

Transactions

of the

American Fisheries Society

EIGHTY-FIRST ANNUAL MEETING
ROCHESTER, NEW YORK
September 12, 13, 14, 1951

Published Annually by the Society
St. Paul, Minnesota
1952

Printed in U. S. A.

Periodical
American Fish. Society
Trans.
181-83
1951-53

2233⁶⁰

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AMERICAN FISHERIES SOCIETY

Printed by
SYNDICATE PRINTING CO.
Minneapolis, Minnesota

THE AMERICAN FISHERIES SOCIETY

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The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1. William Clift.....	1870-1872	New York, N. Y.
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20. Eugene G. Blackford...	1890-1891	Put-in-Bay, Ohio
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36. E. A. Birge.....	1906-1907	Grand Rapids, Mich.

¹A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

37. Hugh M. Smith	1907-1908	Erie, Pa.
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46. George W. Field	1916-1917	New Orleans, La.
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48. M. L. Alexander	1918-1919	New York, N. Y.
49. Carlos Avery	1919-1920	Louisville, Ky.
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51. William E. Barber	1921-1922	Allentown, Pa.
52. Glen C. Leach	1922-1923	Madison, Wis.
53. George C. Embody	1923-1924	St. Louis, Mo.
54. Eben W. Cobb	1924-1925	Quebec, Canada
55. Charles O. Hayford	1925-1926	Denver, Colo.
56. John W. Titcomb	1926-1927	Mobile, Ala.
57. Emmeline Moore	1927-1928	Hartford, Conn.
58. C. F. Culler	1928-1929	Seattle, Wash.
59. David L. Belding	1929-1930	Minneapolis, Minn.
60. E. Lee LeCompte	1930-1931	Toronto, Canada
61. James A. Rodd	1931-1932	Hot Springs, Ark.
62. H. S. Davis	1932-1933	Baltimore, Md.
63. Fred A. Westerman	1933-1934	Columbus, Ohio
64. E. L. Wickliff	1934-1935	Montreal, Canada
65. Frank T. Bell	1935-1936	Tulsa, Okla.
66. A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67. I. T. Quinn	1937-1938	Mexico City, Mexico
68. Fred J. Foster	1938-1939	Asheville, N. C.
69. T. H. Langlois	1939-1940	San Francisco, Calif.
70. James Brown	1940-1941	Toronto, Canada
71. John Van Oosten	1941-1942	St. Louis, Mo.
72. John Van Oosten	1942-1943	(No meeting) ²
73. John Van Oosten	1943-1944	(No meeting) ³
74. John Van Oosten	1944-1945	(No meeting) ³
75. John Van Oosten	1945-1946	(No meeting) ³
76. Joe Hogan	1946-1947	St. Paul, Minn.
77. H. H. MacKay	1947-1948	Denver, Colo.
78. Seth Gordon	1948-1949	Atlantic City, N. J.
79. Milton C. James	1949-1950	Winnipeg, Manitoba
80. Albert S. Hazzard	1950-1951	Memphis, Tenn.
81. W. J. K. Harkness	1951-1952	Ithaca, N. Y.

²The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

³No annual meeting scheduled because of the war.

In Memoriam

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Gerry Fenton, Sault Ste. Marie, Michigan

Eugene S. Cupernell, Los Molinos, Calif.

James Nelson Gowanloch

Ferdinand Hansen, New York, New York

Charles E. Lay, Sandusky, Ohio

Charles Webb Sadler, Sandusky, Ohio

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Harry R. Yale, Chattanooga, Tenn.

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Part 1
Papers

WHAT BECOMES OF THE PhD's IN FISHERIES?

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ABSTRACT

A survey of 343 persons filing doctoral dissertations in fisheries and allied subjects from 1934 to 1949 indicates that 114 are now engaged in fisheries research and teaching. Slightly over half of the 343 are now teaching in colleges and 37 are training future fisheries biologists.

There were 343 persons who filed doctoral dissertations in fisheries and allied subjects from 1934 to 1949, according to a report of the Fish and Wildlife Service (1950). What has become of these persons? This question has significance in the search for qualified personnel for fisheries positions. Its answer will also assist in the training of future doctoral candidates. An attempt has therefore been made to determine the present positions held by the recipients of these 343 doctoral degrees.

It should be pointed out that many of these dissertations were not directly in the fisheries field. Many of the candidates probably never thought of themselves as fisheries students nor ever planned to enter the field. The dissertations were roughly classified as to subject matter in the report and these classes have been considered separately in the present analysis. When the distributions of the various positions held were similar and when the subjects were closely related, the classes were combined to shorten Table 1.

The membership lists of many scientific societies and several directories of scientific personnel were examined, but the author was unable to learn the present addresses of 48 of the candidates (14 percent). It is unlikely that many of these are now in the fisheries field because the methods of checking fishery personnel were more efficient than those in some other areas. Nine of those not located were women, some of whom may have changed their names and fields of activity since receiving their degrees. Three others were Oriental students who have probably returned to their native countries.

Only 85 of the 343 men and women are members of the American Fisheries Society, 122 are members of the American Society of Limnology and Oceanography, and 64 are members of the American Society of Ichthyologists and Herpetologists. If the total is limited to the 114 persons now engaged in fisheries research and teaching, 75 are in the A.F.S., 83 in the A.S.L.O., and 55 in the A.S.I.H.

The fisheries research jobs were classified as to the employing agency. The academic agencies included those organizations not directly concerned with management, such as the Marine Biological Laboratory, Scripps Institute of Oceanography, American Museum, Illinois Natural History Survey, and some aquaria. The Canadian agencies were the

TABLE 1.—*Present status of persons granted PhD degrees from 1934 to 1949 with dissertations on the management and ecology of fishes, and allied subjects, enumerated on the basis of job, subject of dissertation, and membership in professional societies.*

Type of job	Subjects of doctoral dissertations ¹									Societies			
	Management	Limnology	Taxonomy	Ecology	Crustacea	Physiology	Pollution	Oceanography	Miscellaneous	Total	Fisheries	Limnology and Oceanography	Ichthyology and Herpetology
Fisheries research													
Academic agencies...	1	4	7	2	2	5	..	4	..	25	10	17	12
Canadian agencies...	1	1	2	7	1	1	..	..	..	13	6	8	3
U. S. federal.....	4	4	7	4	2	2	1	..	..	24	19	19	11
State.....	4	4	7	..	..	..	..	..	..	15	13	10	7
Fisheries teaching.....	8	6	6	8	7	2	..	..	..	37	27	29	22
Total fisheries.....	18	19	29	21	12	10	1	4	..	114	75	83	55
College teaching													
Zoology.....	1	21	10	12	18	23	..	2	1	88	8	29	6
Medical.....	1	2	..	..	5	15	..	1	..	24	..	2	2
Other.....	..	9	1	2	6	4	2	5	6	35	..	3	..
Other biological.....	1	5	..	4	2	2	1	1	3	19	1	3	1
Other.....	..	1	..	3	1	2	4	..	2	13	1	1	..
Deceased.....	..	..	..	1	..	..	1	..	..	2	..	..	..
Unknown.....	2	5	5	5	5	12	5	2	7	48	..	1	..
Totals.....	23	62	45	48	49	68	14	15	19	343	85	122	64

¹Each heading includes the following subjects listed in Special Scientific Report:

Fisheries No. 31:

Management: Management, Game fish, Marine fisheries, and Techniques.

Limnology: Limnology.

Taxonomy: Taxonomy, Life history studies, and Faunas and manuals.

Ecology: Ecology, Food and food organisms, and two items from Miscellaneous.

Crustacea: Crustacea, Shellfish, and Plankton.

Physiology: Physiology, Morphology, Development, Diseases and parasites, and one item from Miscellaneous.

Pollution: Pollution.

Oceanography: Oceanography.

Miscellaneous: Fish poisons, Historical studies, Seafood poisons, Water quality, Hydrology, and three items from Miscellaneous.

Fisheries Research Board of Canada and the Canadian Wildlife Service. Among the U. S. Federal Agencies were included the Fish and Wildlife Service, Public Health Service (only those working in special research laboratories on fisheries problems were here included), and, because he did not fit anywhere else, the Executive Vice President of the Sport Fishing Institute. The fisheries teaching classification included

those teaching courses in fishery biology and those teaching in closely allied fields such as limnology, oceanography, and aquatic entomology at colleges which train fisheries biologists.

Now in fisheries positions are 78 percent of those whose dissertations dealt with management, 64 percent of those in taxonomy, 44 percent of those in ecology, and 31 percent of those in limnology. These four classifications, which include 52 percent of the theses, contributed 76 percent of the group which have gone into fisheries employment.

Slightly over half of those receiving the Doctor of Philosophy degree (54 percent) are now teaching in colleges. About half of these are teaching in zoology or biology departments having little connection with fishery research programs, 24 are in medical colleges, and others are teaching botany, geology, engineering, and psychology. Other biological fields into which 19 of the candidates have gone include insecticide work, public health, biological supply, and soil conservation. Some of the candidates are now in fields somewhat removed from their thesis topics: housewives, testing bureaus, airlines, and armed services.

LITERATURE CITED

U. S. FISH AND WILDLIFE SERVICE

1950. Doctoral dissertations on the management and ecology of fisheries. U. S. Dept. Interior, Fish and Wildl. Serv. Spec. Sci. Rept.: Fisheries No. 31, pp. 1-35.
-

ESTIMATION OF FISH POPULATIONS IN MICHIGAN LAKES¹

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ABSTRACT

Fish population estimates, using trap nets in the Petersen mark-and-recapture procedure, were made during 1948, 1949, and 1950 on Sugarloaf Lake in Washtenaw County and during 1950 on Fife Lake in Grand Traverse County, Michigan. The nets were of two sizes: 3-foot and 6-foot. The lake acreages are 180 and 575, respectively. The important fish species were bluegill, pumpkinseed sunfish, yellow perch, largemouth bass, smallmouth bass, black crappie, northern pike, yellow and brown bullheads, and warmouth. The study was limited to fish over 6 inches in length.

In four separate netting periods, 17,887 fish (approximately half bluegills) were marked by fin clipping and released, and 2,991 of these (17 percent) were recaptured.

Distinctive markings were used for fish from two halves of each lake, and recaptures were tabulated accordingly. Marked fish, liberated at a common release station near the center of the lake, showed a tendency to return to the same half of the lake where marked; but the amount of this "homing" was not sufficient to invalidate the population estimations. Distinctive marking for two groups of stations, separated systematically according to even and odd numbers in series, gave returns which showed no marked tendency for fish to return to their home trap-net site.

The three separate estimations of populations of legal-size fish in Sugarloaf Lake, computed by the Schumacher and Eschmeyer formula, gave 17,648 fish for the fall estimate of 1948, a total of 15,531 fish for the spring estimate in 1949, and 22,178 fish in the spring of 1950. These totals, correlated with the numbers of trap-net stations on which the estimates were based (30, 20, and 40, respectively) suggest, by extrapolation, that the true population figure is something less than 30 thousand. The average computed total for the 3 years was 18,452 fish, or 102 fish and 43.1 pounds per acre. Estimations by the Schnabel formula gave totals which were generally a little higher than by the Schumacher and Eschmeyer formula. For Fife Lake the estimated total population was 99,056 fish or 172 fish of 62.3 pounds per acre. In both lakes the bluegill made up over half of the totals.

Records of marked and unmarked fish in anglers' creels immediately following the trap netting provided another basis for estimating the fish populations in Sugarloaf Lake in 1949 and 1950. Such estimates were about double the estimates based on trap-net recaptures. The reason for the difference was not determined.

INTRODUCTION

Research and management on inland sport fisheries have reached the stage where a knowledge of total populations of fish is essential to any major advance in this science. Food habits, ecological relations, life

¹Contribution from the Michigan Institute for Fisheries Research.

histories, stocking for introductions, and a basic pattern of regulations have been studied and applied where some application has been apparent. While there is still much need for research in ichthyology and basic limnology, a major emphasis must be on populations of fish.

The field of fish management includes: (1) stocking for maintenance, (2) restrictive regulations, and (3) various approaches to habitat improvement including population control. In these three aspects of fish management, the relative importance of which is not necessarily in the above order, we are in a transition from the descriptive to the quantitative approach. To evaluate satisfactorily changes in fishing regulations, the contribution made by maintenance stocking, or any type of habitat improvement, it is necessary to be able to estimate directly the total number of fish present in any water, or else to get an indirect estimate of the population through quantitative creel census.

While the use of the electric shocker is proving invaluable in population estimates on streams, no comparable collecting tool has been devised for lakes. In lakes the general procedure must be one of sampling to give an estimate of the whole, and then evaluating the sources of bias in this procedure. A few significant population estimates have been made on small ponds which could then be drained (Schumacher and Eschmeyer, 1943) or poisoned (Fredin, 1950; Krumholz, 1944), allowing a check on the accuracy of the estimates, but on most lakes this is not possible.

Population estimates, by the Petersen method of mark-and-recapture (Ricker, 1948) as elaborated mathematically by Schnabel (1938) and by Schumacher and Eschmeyer (*op. cit.*), are dependent upon several assumed conditions (Ricker, *op. cit.*) of fish behavior and distribution. On the one hand each of the several assumptions may be critical to the acquisition of results of even usable accuracy. On the other hand, the validity of each assumption is not always (in fact, is seldom) obvious from available information on habits of the different species, especially for fish in lakes of considerable area. Estimates made on small ponds, subsequently drained, have generally been of usable accuracy (e.g., Schumacher and Eschmeyer, *op. cit.*).

The critical assumptions are that marked fish must retain their mark, must not suffer unrecorded mortality at a greater rate than do unmarked fish, and must be equally susceptible to subsequent recapture with unmarked fish. The latter assumption means that marked fish must be distributed either at random over the lake or in numerical proportion among the unmarked population. If the distribution of marked fish is not at random or proportional, then the distribution of netting effort must be intensive and random.

Several questions are of paramount importance: (1) Should fish be liberated at the netting site where captured, or at some distant point? If liberated at the point of capture, say by a trap net, should they be liberated in front of the net where recapture would be likely, or behind

the net where, in shallow water, recapture would be unlikely? (2) Does the individual fish have its own home niche with a limited range of normal movement? If so, what is this range of movement, and is the home niche a seasonal phenomenon? (3) When individual fish are removed from a home niche to some remote spot, do they become wanderers and are they therefore more susceptible to recapture by intercepting nets than are fish which have not been disturbed? To what extent and how quickly do transplanted fish return to a home niche? Generally the significance of these questions is greater in large lakes than in small ones.

The present paper deals with trap-net population estimates on two Michigan lakes on which experimental fishing regulations have been in effect (Cooper and Christensen, 1951). The aims have been to determine the size of the fish populations for comparison with the total anglers' catch computed by creel census, to calculate the amount of survival from plantings of hatchery smallmouth bass fingerlings (marked by fin clipping), and to study the habits and distribution of fishes which are significant in the assumptions of the mark-and-recapture procedure.

SUGARLOAF LAKE

Sugarloaf Lake is located near Waterloo, Washtenaw County, in glacial moraines. The lake was mapped in 1944 by sounding on a grid pattern through the ice. The area is 180 acres and the greater part has depths between 2 and 5 feet. A very small area is over 10 feet, and the maximum depth is 20 feet (Figure 1). Aquatic vegetation is abundant over most of the lake, except within the 10-foot contour. The fish population is typical of southern Michigan lakes, including northern pike, largemouth bass, bluegill, pumpkinseed sunfish, warmouth, black crappie, yellow perch, yellow and brown bullheads, bowfin, and several forage species. With about 80 cottages on the lake and public access, fishing intensity is heavy.

Population estimates on Sugarloaf Lake were made by trap netting in the fall of 1948 (October 20-November 24), in the spring of 1949 (April 20-May 22), and in the spring of 1950 (April 18-June 1). The trap nets used were either 3-foot or 6-foot nets as described by Crowe (1950). The 3-foot net had a single pot 3 by 3 by 6 feet, 12-foot wings and hearts, 100-foot lead, 2½-inch and 3-inch stretched mesh, and #12 and #9 thread seine twine. The 6-foot net had a double pot, 6 by 4 by 16 feet, 20-foot wings and hearts, 150-foot lead, 2½-, 3-, and 4-inch mesh (back pot, front pot, and lead, respectively), and #15 and #12 thread seine twine. The nets were fished at 30 stations in 1948, 20 in 1949, and 40 in 1950. For experimental purposes the stations were grouped, and released fish were marked differently, for each half of the lake (east and west), and all fish were released at a central station. The distribution of netting stations over the lake was sys-

tematic, and designed to give uniform distribution of netting effort, with the smaller nets fishing in shallower water. The patterns of net stations in 1948 and 1949 were similar to those employed in 1950 (Figure 1), but with fewer stations more widely scattered.

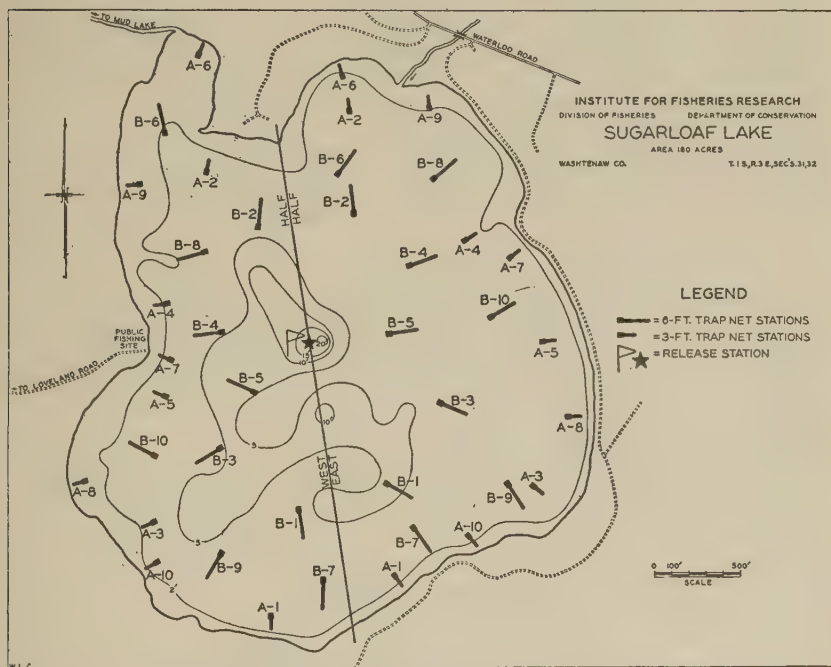


FIGURE 1.—Sugarloaf Lake, Washtenaw County, Michigan, showing the locations of 40 trap-net sites and one release station used in the 1950 population estimate.

The procedure was to fish a net at a given station for 3 nights, and to lift the nets and process the fish each morning. After a 3-day set, the net was moved to a new station. The stations (numbered in Figure 1) were fished in numerical order, with nets of each size fishing concurrently in the two halves of the lake. Usually there were six nets in continuous operation. In 1948, the procedure was to fish a complete round of the 30 stations, followed by 2 weeks of continuous netting at 8 stations; in 1949, two complete rounds were made of the stations for 3-foot trap nets and four complete rounds were made of the 6-foot trap-net stations. During 1950, the 1949 procedure was followed for the 20 stations numbered 1 to 5, then one round was made of stations numbered 6 to 10. The general procedure was to fish several nets on a systematic schedule at numerous stations continuously for 4 to 6 weeks, marking and recording all fish.

FIFE LAKE

Fife Lake is located in Grand Traverse and Kalkaska counties. Its area is 575 acres and the maximum depth is 55 feet. In 67 percent of the lake area, the water is less than 20 feet deep, and submerged aquatic plants are generally abundant out to a depth of 15 feet. The fish species present, listed in order of their importance to anglers, are yellow perch, bluegill, pumpkinseed sunfish, northern pike, largemouth bass, smallmouth bass, rock bass, black crappie, walleye, and bullheads. There are about 80 cottages on the lake, and fishing is of moderate intensity.

For the population estimate, 3-foot and 6-foot trap nets were fished from June 16 to July 19, 1950, at 60 stations (numbered 11 to 70). Most of these stations were located in water less than 20 feet deep and were divided equally between east and west halves of the lake, and equally by quarters within each half. Netting (3 nights per station) was systematized by starting six nets at stations numbered 11, 21, 31, 41, 51, and 61, and then moving the nets to stations in the 2-series (12, 22, 32), etc. The result was that a 6-foot net was being fished continuously in each quarter of the lake, and a 3-foot net continuously in each half. Separate release stations were used for the two halves of the lake (Figure 2).

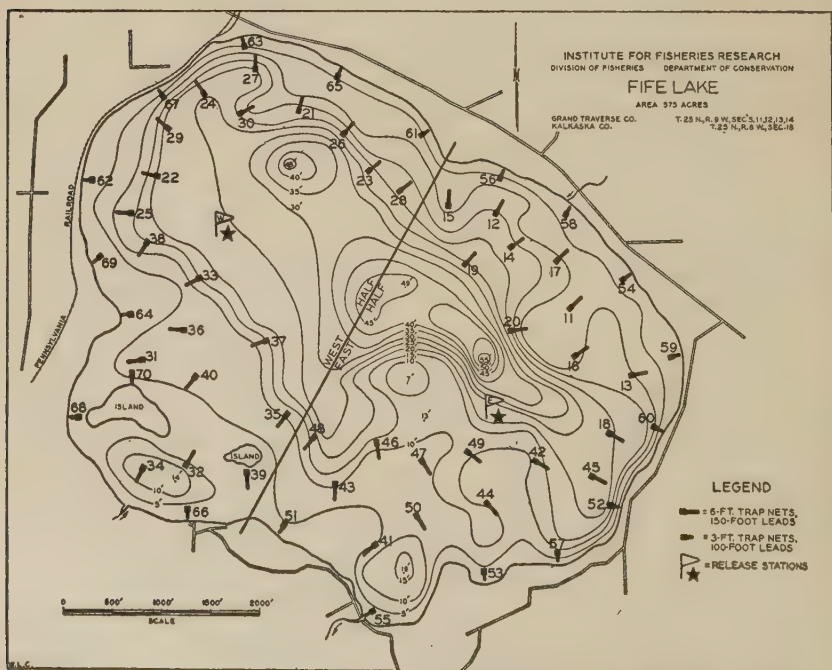


FIGURE 2.—Fife Lake, Grand Traverse County, Michigan, showing the locations of 60 trap-net sites and 2 release stations used in the 1950 population estimate.

On both Sugarloaf and Fife lakes, fish were marked by fin clipping before release, using a different fin for each half of the lake and for each year. Capture and recovery records including type of marking were kept separately for each station. Recaptures were again transported to the release station. It is not believed that fin regeneration influenced the results during the short time that each study was in progress. In addition to maintaining the netting records, the field party regularly examined the lake surface and shoreline for marked fish which might have been killed by netting operations. An intensive creel census gave daily figures on the removal of marked and unmarked fish by anglers. This study is concerned with pike larger than 14 inches in length and other species over 6 inches since smaller fish were not taken commonly by the trap nets.

NUMBER OF FISH MARKED AND RECOVERED

The total number of fish marked and released in the four population studies was 17,887 and the total number of recaptures was 2,991 fish or 17 percent (Table 1). The recovery figure is a little misleading because some individual fish may have been counted as recoveries more than once (e.g., black crappie in Sugarloaf Lake, 1950, Table 1). The bluegill far outnumbered other species in total captures and gave the greatest number of recaptures. Bullheads, black crappie, pumpkinseed sunfish, rock bass, and largemouth bass were other predominant species. Angling records suggest that the yellow perch is far more abundant in the lakes than is indicated by the netting records, and it appears that it is difficult to catch perch with the type of trap nets used here.

HOMING IN REDISTRIBUTION

Where fish were marked differently in the two halves of Sugarloaf Lake, and the recoveries were tabulated accordingly, the analysis gives a rough measure of the tendency ("homing") of the fish to return to the part of the lake where first captured. Because the distinctive marking was not applied to each of the numerous netting sites, some of the exactness to be desired in the study was lost. It might be inferred that the stimulus which directed a particular fish to his home half of the lake was an urge to return to his original niche. However, this assumption may not be correct, since general habitat conditions may have been a factor, or peculiarities in the (systematic) pattern of netting sites and netting dates may have favored recapture in one half of the lake over the other half. Recoveries in the home half and in the opposite half of the lake were distributed rather evenly throughout the several weeks of each netting period.

There was a significant tendency for fish, released at one central station, to be recaptured in the same half of the lake where they were first captured and marked. The 12,246 fish marked in Sugarloaf Lake

(Table 1) included 6,055 fish marked in the west half and 6,191 fish marked in the east half. Of 2,682 recoveries on Sugarloaf (of which 1,393 were marked in the west half, and 1,289 were marked in the east), 1,590 were recovered in the same half where marked, while 1,092 were recovered in the opposite half. Furthermore, the tendency was consist-

TABLE 1.—Numbers of fish marked and released (a) and numbers recaptured (m) in trap-net population studies, Sugarloaf and Fife lakes during 1948, 1949, 1950.

Kind of fish	Sugarloaf Lake						Fife Lake	
	1948		1949		1950		1950	
	a	m	a	m	a	m	a	m
Bluegill, <i>Lepomis macrochirus</i>	1,113	46	2,545	252	3,742	717	2,773	70
Rock bass, <i>Ambloplites rupestris</i>	82	3	67	8	386	107	517	29
Pumpkinseed, <i>Lepomis gibbosus</i>	60	2	303	45	238	48	727	24
Black crappie, <i>Pomoxis nigromaculatus</i>	218	60	229	168	102	116	680	25
Largemouth bass, <i>Micropterus salmoides</i>	136	5	78	8	176	41	302	26
Smallmouth bass, <i>Micropterus dolomieu</i>							198	30
Bullheads, <i>Ameturus natalis</i> , <i>A. nebulosus</i>	409	334	159	69	579	398	224	93
Walleye, <i>Stizostedion vitreum</i>							77	2
Northern pike, <i>Esox lucius</i>	19	2	25	4	89	18	58	1
White sucker, <i>Catostomus commersonni</i>							72	8
Warmouth, <i>Chaenobryttus coronarius</i>	41		311	31	566	101		
Yellow perch, <i>Perca flavescens</i>			7		218	15	13	1
Bowfin, <i>Amia calva</i>	80	6	75	21	153	56		
Gars, <i>Lepisosteus osseus</i> , <i>L. productus</i>	22	1	9		9			
Total all species.....	2,180	459	3,808	606	6,258	1,617	5,641	309

ent for the two halves of the lake. West half fish tended to return to the west half, and east fish to the east, in two of the three periods, whereas in 1948 the tendency was for fish from both halves to be recaptured in the west (Table 2). The preponderance of homing fish amounted to 498, or 18 percent of the total. An analysis by Chi-square on the marking and recapture data, combined for the 3 years, shows a highly significant tendency for "homing." Of 1,393 recaptures marked in the west half, 697 recaptures in the west half would be expected on an equal-chance basis, whereas 855 were actually recaptured. Similarly, of 1,289 marked in the east half, 645 recaptures would have been expected, while 735 were obtained. The respective values for Chi-square are 72.1 and 25.4, with $P < .001$ in both instances.

Even though this analysis shows a high degree of significance, it does not necessarily follow that the result is an error in the population estimate to the extent (18 percent) of the homing tendency. Homing would be effective in this degree only if the fish returned to the original netting station. An allowance must be made for the possibility that some fish started for, but did not reach, the home netting station. A second qualifying factor is that the extensive pattern of (numerous) netting stations would partially compensate for the "homing error." These factors are the subject of research now in progress.

The 5,641 fish marked in Fife Lake included 2,723 marked in the west half (1,885 at odd-numbered stations, 838 at even-numbered stations), and 2,918 marked in the east half (1,739 at odd- and 1,179 at even-numbered stations). The 309 recaptures (Table 1) had the follow-

TABLE 2.—Analysis of recaptures of marked fish in Sugarloaf Lake according to whether recovery was in same (S) or opposite (O) half as where originally marked during 1948, 1949, 1950.

Kind of fish	Half of lake where marked	Year						Totals	
		1948		1949		1950			
		S	O	S	O	S	O	S	O
Bluegill.....	West	23	5	74	46	183	160	280	211
	East	5	13	81	51	237	137	323	201
Rock bass.....	West	.....	2	3	1	18	27	21	30
	East	.....	1	2	2	45	17	47	20
Pumpkinseed.....	West	1	.....	14	3	18	2	33	5
	East	1	.....	26	2	19	9	46	11
Black crappie.....	West	10	6	84	29	38	12	132	47
	East	27	17	11	44	33	33	71	94
Largemouth bass.....	West	2	1	1	1	21	2	24	4
	East	.....	2	5	1	10	8	15	11
Bullhead.....	West	138	82	15	20	139	84	292	186
	East	36	78	19	15	95	80	150	173
Pike.....	West	.....	.....	2	2	8	2	10	4
	East	1	1	.....	.....	2	6	3	7
Warmouth.....	West	.....	.....	10	10	20	21	30	31
	East	.....	.....	6	5	42	18	48	23
Yellow perch.....	West	.....	.....	.....	.....	2	4	2	4
	East	.....	.....	.....	.....	5	4	5	4
Bowfin.....	West	6	.....	6	5	18	11	30	16
	East	.....	.....	7	3	20	7	27	10
Gar.....	West	1	.....	.....	.....	.....	.....	1	.....
	East	.....	.....	.....	.....	.....	.....	.....	.....
All species.....	West	181	96	209	117	465	325	855	538
	East	70	112	157	123	508	319	735	554
	West & East	251	208	366	240	973	644	1,590	1,092

ing distribution according to the lake half and according to even- and odd-numbered stations, given as percentages of the numbers marked and (in parentheses) the numbers of fish recaptured:

Marked at:

Recovered at:

	West-odd	West-even	East-odd	East-even
West-odd (1885)	2.92 (55)	2.18 (41)	0.58 (11)	0.16 (3)
West-even (838)	2.74 (23)	1.07 (9)	0.48 (4)	1.43 (12)
East-odd (1739)	0.52 (9)	0.52 (9)	1.78 (31)	1.44 (25)
East-even (1179)	1.19 (14)	0.93 (11)	2.12 (25)	2.29 (27)

Of the 1,885 fish marked in the west half at odd-numbered stations, 55, or 2.92 percent, were recaptured at west-odd stations, 41, or 2.18

percent, at west-even stations, etc.; of the 838 fish marked at west-even stations, 23, or 2.74 percent, were recaptured at west-odd stations, etc. These figures support two conclusions quite definitely.

First, fish marked at odd-type or even-type stations did not tend to be recaptured more frequently at the same type station as where marked, which means that they did not show a predominant tendency to return and be recaptured at their home net sites. The recapture figures which are significant to the point in question are only those for recaptures in the same half of the lake where marked and released. Thus in the above tabulation there are four pairs of data which should be considered as follows:

Same	Opposite	Difference
55	41	+14
9	23	-14
31	25	+ 6
27	25	+ 2

The mean difference is +2, and t is 0.6. It is highly improbable that the fish returned more frequently to the "home" stations.

Second, the fish were recaptured approximately twice as frequently in the same half of the lake where marked and released. This result was to be expected in view of the fact that release stations were used for each of the two halves of the lake, making recapture more likely in the home half. This conclusion is so obvious in the preceding tabulation that a t -test on the data is believed to be unnecessary. In appraising the homing tendency, one might weigh the returns in proportion to the distance between release stations and sites of recapture, on the assumption that the probability of recapture is a function of the distance which must be traveled to the recapture site. When the average distances in hundredths of a mile between the release stations and netting sites (as subdivided) are multiplied by the corresponding figures on percentage of recapture for all species, the resulting distances and migration indexes are obtained as follows:

	From	To stations			
		West-odd	West-even	East-odd	East-even
Average distances	West release....	30	32	68	66
	East release	68	69	30	28
Migration indexes	West-odd	88	70	39	11
	West-even	82	34	33	94
	East-odd	35	36	53	40
	East-even	81	64	64	64

The absence of a homing tendency for even- or odd-numbered stations is again apparent in these "corrected" figures. The eight index figures which represent recapture in the home half may be compared statistically with the opposing eight values:

Same half: 88, 70, 82, 34, 53, 40, 64, 64
 Opposite: 35, 36, 81, 64, 39, 11, 33, 94

in which the mean difference is 12.8, t is 1.08, and the probability of difference is only 70 percent. We conclude then that the tendency for fish to be recaptured more frequently in their home half of the lake could have been largely a function of distance to the nets, rather than being due to homing instinct.

POPULATION ESTIMATES

Estimates of populations were made in all instances by the formula of Schumacher and Eschmeyer (1943) and in most instances were repeated by that of Schnabel (1938). Only estimates by the former formula (generally somewhat lower than by the latter) are cited here. Computations were made for each species separately (necessary because of the species differences in rate of recovery), using the following summation formula for records over the period of netting:

$$\text{Population} = \frac{\text{Sum of } [m^2 \quad (m + u)]}{\text{Sum of } (nm)}$$

in which m is the number of marked fish recaptured, u is the number of unmarked fish caught in any day, and n is the accumulated total number of marked fish presumed to be alive in the lake at the beginning of that particular day. Thus n accumulates by the addition of newly marked fish and the subtraction of marked fish removed from

TABLE 3.—*Estimates by the Schumacher and Eschmeyer formula, of legal-size fish in Sugarloaf Lake (180 acres) and Fife Lake (575 acres) in Michigan, based on trap-net recaptures of marked fish.*

Species ¹	Lake						
	Sugarloaf					Fife	
	1948	1949	1950	Three-year averages		1950	
	Number	Number	Number	Number	Lbs./acre	Number	Lbs./acre
Bluegill	12,494	11,641	14,012	12,715	18.6	56,511	23.6
Rock bass	972	232	997	734	1.4	4,845	2.0
Pumpkinseed	775	883	825	827	1.3	14,186	5.9
Black crappie	511	302	126	313	0.7	13,673	12.6
Largemouth bass	1,718	367	518	868	6.6	1,789	4.0
Smallmouth bass						7,264	12.5
Bullheads	543	374	992	636	2.3	424	0.6
Northern pike	80	119	271	157	1.9		
White sucker						364	1.1
Warmouth		1,430	2,389	1,273	2.3		
Yellow perch			1,615	538	0.7		
Bowfin	478	183	433	365	7.0		
Gars	77			26	0.3		
Totals	17,648	15,531	22,178	18,452	43.1	99,056	62.3

¹Too few recaptures of walleyes for an estimate; same for pike, warmouth, perch and gars in certain instances.

the lake by angling or other mortality. Variances and standard errors were calculated by additional formulae given by Schumacher and Eschmeyer (*op. cit.*).

Among the computed totals (Table 3) the bluegill led the list of species, making up more than 50 percent of the populations of the two lakes. Rock bass, pumpkinseed sunfish, black crappie, largemouth and smallmouth bass, bullheads, and warmouth were other important species. There is a general absence in the lakes of non-predaceous fish of large size. The three estimates for the various years of total population in Sugarloaf Lake were 15,531, 17,648, and 22,178 with an average of 18,452 fish, or 102 fish and 43.1 pounds per acre. The three estimates were correlated closely with the numbers of trap-net stations on which the estimates were based (20, 30, and 40, respectively) and by extrapolation one might conclude that the true population figure was something closer to 30,000 fish. This hypothesis would mean that the estimates based on the lower numbers of stations were in error (underestimated) in that the effective "fields" of the trap-net stations did not completely overlap. Carrying this thought one step farther, if the use of trap nets at the rate of 9, 6, and 4.5 acres per net-station gave underestimations of 50 to 30 percent, the correct size of the trap-net field would be estimated at about 3 acres. Obviously there is much conjecture in the preceding thoughts. The idea that these estimations on Sugarloaf were considerably in error because the "effective field" of each net was not large enough is not compatible with the results of analysis of recapture records. If marked fish were redistributed at random over the lake (not unduly concentrated within trap-net "fields"), the degree of total coverage would not be a critical factor. The analysis of recaptures cited above showed that a "homing" tendency of marked fish was not over 18 percent for Sugarloaf Lake and much less than that for Fife Lake. There remain, for an explanation of the variation in Sugarloaf estimates, the possibilities that an accumulation of minor experimental errors are involved and that there may have been some annual fluctuation in numbers of fish present.

Standard errors of the computed population estimates for Sugarloaf Lake were generally about 5 to 8 percent for the 12 to 14 thousand bluegills and from 10 to over 50 percent for species numbering less than a thousand. The percentages of error were similar for the larger population estimates for Fife Lake. For the general applications which might be made of these population estimates, the errors appear to be of inconsequential magnitude. The total population of Fife Lake, of 99,056 fish, was equivalent to 172 fish or 62.3 pounds per acre.

ESTIMATES FROM ANGLING RECORDS

Total population estimates were also made from creel census records interpreted in conjunction with the records on marked fish in the lake. The census on Sugarloaf Lake recorded approximately 14 percent of

all angling effort. In 1949 and 1950 the census clerk recorded marked and unmarked fish separately for three consecutive 4-week periods immediately following the trap netting and marking. Generally, the anglers fished for the species which were most important in the trap netting. The numbers of marked fish of species most commonly taken by angling which were presumed to be present and alive in the lake at the termination of trap netting, and the creel census records are given

TABLE 4.—*Marked and unmarked fish in anglers' creels following trap netting, and estimates of fish populations, for selected species in Sugarloaf Lake.*

Year and species	Periods following netting				Marked fish in lake	Estimates based on	
	First 4 weeks		Next 8 weeks			First period	Two periods
	Marked	Un-marked	Marked	Un-marked			
1949							
Bluegill.....	46	482	16	236	2,236	25,670	28,130
Pumpkinseed.....	3	56	3	37	256	5,030	4,220
Rock bass.....	2	27	1	11	61	880	830
1950							
Bluegill.....	125	585	86	634	3,505	19,910	23,750
Pumpkinseed.....	12	79	14	126	222	1,680	1,970
Rock bass.....	2	43	5	63	380	8,550	6,130
Largemouth bass.....	4	74	16	157	173	3,370	2,170
Bullhead.....	1	8	8	20	571	5,140	2,350
Warmouth.....	3	16	6	32	565	3,580	3,580
Bowfin.....	1	13	4	42	148	2,070	1,780

in Table 4. The figures appear to be especially good for the bluegill, and fair for the pumpkinseed and largemouth. Data for the bluegill show a rather definite decrease in ratio of marked to unmarked fish over the three 4-week periods, but such a trend is not obvious for other species. In this instance the estimates were made by a direct-proportion formula in a single computation for each species.

The estimates based on census figures, for bluegills, show variation depending upon whether records for only the first 4 weeks or for the 12 weeks are used. The decrease in relative numbers of marked bluegills in the creel records may have been an expression of greater mortality of the marked bluegills or the result of recruitment from growth, or both. The lesser (earlier) figures should be more comparable with the trap-net estimates. The creel estimates for all species are about double the trap-net estimates. The grand totals for all species in 1949 and 1950 are around 35 and 45 thousand as compared to 15 and 20 thousand estimated from trapping. The reason for the difference is not apparent. Mortality, recruitment, and bias in sampling are possibilities. One argument supporting the estimates from creel data is that the com-

bination of netting and angling is theoretically the better procedure, because the one method of collecting avoids some of the sources of bias of the other.

ACKNOWLEDGMENTS

Many individuals in the Institute for Fisheries Research have made important contributions to this study. The field party members included R. C. Barber, J. H. Claridge, G. F. Myers, D. E. Parsons, K. E. Proshek, R. F. Stinauer, D. F. Thomas, and H. J. Vondett. Mr. Thomas also collected and summarized the creel census data and K. E. Christensen and R. N. Schafer assisted in computations. The late Henry E. Predmore, Jr. contributed much in planning and supervision. Dr. A. S. Hazzard has made numerous helpful suggestions.

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THE MORTALITY AND GROWTH OF MARKED AND UNMARKED LAKE TROUT FINGERLINGS IN THE PRESENCE OF PREDATORS¹

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ABSTRACT

Two experiments were conducted between October 4, 1948, and October 25, 1949, at the State Fish Hatchery at Marquette, Michigan, to determine the effect of predation on fin-clipped lake trout, *Cristivomer n. namaycush* [Walbaum], fingerlings. One experiment involved 4,000 unmarked fish and 4,000 clipped fish confined in the presence of adult brook trout, brown trout, rainbow trout, and lake trout.

In a smaller experiment, another pond was divided by a fish-tight screen and bulkhead. In the lower half, weighted brush piles were added to provide cover. The upper half was left without cover. Into each half of this pond 500 unmarked fish and 500 marked fish were released, along with various predator fish. The small experimental pond was covered with chicken-wire screen to prevent bird predation.

Observation of deaths caused by factors other than predation, plus the counts of survivors at several examinations revealed the numbers of fish lost to the predator fish between various dates. Chi-square analysis of predation loss in the two experiments shows that the proportion of marked fish among the predator-caused mortalities was not significantly greater than for unmarked fish. Statistical analysis shows no significant difference in the growth of marked and unmarked fingerling lake trout in the presence of predatory fish.

Clear-cut results concerning the effect of cover on mortality of marked and normal fish in the presence of predators was not obtained. Unobserved deaths of predator fish in both parts of the split pond invalidated efforts to keep the amount of predation equal at all times in the two experimental enclosures.

In the period 1944-1948, over 450,000 fin-clipped lake trout fingerlings were planted in Lakes Michigan and Huron as part of a general study of this valuable food fish by the Great Lakes Lake Trout Committee (Hazzard, 1947). The effects of fin-clipping on growth and survival have been described by Shetter (1951). Studies on fingerling-size centrarchids in Indiana ponds in the presence of predator fish led to the conclusion by Ricker (1949) that the fin-clipping of young large-mouth black bass resulted in a survival of marked fish only 52 percent as great as that of unmarked specimens. If a similar effect was caused by removing fins from lake trout fingerlings, it would have an important bearing on the interpretation of the results of the large-scale releases of marked fingerlings in Lakes Michigan and Huron.

¹Contribution from the Michigan Institute for Fisheries Research.

This paper describes the results of experiments with marked lake trout fingerlings held in shallow hatchery ponds together with predatory species. The experiments were conducted during the period from October 4, 1948, to October 25, 1949, at the State Fish Hatchery at Marquette, Michigan.

EXPERIMENTAL PROCEDURE

Two experiments were initiated. One large-scale experiment involved 4,000 unmarked and 4,000 marked fingerling lake trout placed in the same pond with large brook trout, brown trout, rainbow trout and lake trout as predators. Among the marked fish, 1,000 each were marked by the removal of the dorsal and adipose fins, the right pectoral fin, the left pectoral fin, and the right pelvic fin. The combination and the single fins were clipped in the large-scale planting experiments referred to above. The experimental fish were marked, weighed, counted, and placed in the large circular display pool of the hatchery on October 6, 1948. To determine the initial average lengths of the experimental fish, 12.5 percent of each of the groups (taken at random) were measured individually. The predator fish, consisting of two each of adult brook trout, brown trout, rainbow trout, and lake trout, were measured and weighed and introduced on October 7 and 8, 1948.

The pool into which the experimental fingerlings and the predators were placed was approximately 30 feet in diameter and was operated with a water depth of 36 inches. It had vertical sides of stone blocks. The water came from one upright supply pipe capped by a fine-meshed screen several inches above the water level. The outlet was blocked by a fine-meshed screen, and the water level was controlled by stop-logs set in a small concrete bulkhead.

A smaller experiment was initiated in one of the rectangular raceways to run concurrently with the large-scale experiment in the circular pool. This raceway was divided into two separate experimental ponds by placing a fish-tight stop-screen on sheet-piling, approximately in the middle of the raceway. The upper half (34.5 feet by 8.5 feet) was left in the normal condition characteristic of most hatchery ponds where the only cover available is under overhanging grass and sod. The lower half (30 feet by 8.5 feet) had cover added by the placement of four small brush piles at irregular intervals. Broken paving blocks were loaded on water-logged tamarack and cedar branches to form the shelters. Depth of water in the split pond ranged from 15 inches at the edges to 22 inches in the middle.

Into each part of this pond 500 unmarked lake trout fingerlings and 500 marked fish were placed. Of the latter, 125 each were given the dorsal-adipose mark, the right pectoral mark, the left pectoral mark, and the right pelvic mark. Marking, counting, and sorting took place on October 4, 1948. All fish were measured individually to determine the average sizes of the various groups. One brown trout and one

yellow pike-perch were placed in each half of the experimental pond on October 5, 1948. The predators were changed at a later date for various reasons. To prevent bird predation the entire pond was covered completely with chicken-wire screen (mesh size approximately 1 inch by 1½ inches).

The experiment in the split pond was set up in an attempt to determine whether there was any significant difference in the mortality rates of marked and normal fish exposed to predators in the presence or absence of escape cover.

All experimental fish were fed a finely ground diet of 50 percent pork melts and 50 percent horse hearts. During the first 6 months, fish in the circular pool were fed 14 pounds of this mixture weekly, while those in the split pond received 6 pounds weekly. During the last 6 months, the two ponds each received 10 pounds of the diet weekly.

THE CIRCULAR-POND EXPERIMENT

It was not practicable to cover the circular pond to eliminate the factor of bird predation on the experimental fish. This pond therefore was probably subjected to predation by birds and mammals (such as mink, otter, and weasel) as well as by the large trout which were introduced. The vertical sides and the greater depth of water probably limited predation by birds and mammals to some extent. This pond was inspected and the surviving fish were measured on March 8, 1949, May 24, 1949, and on October 25, 1949. The numbers of fish present on those dates are shown in Table 1.

Daily inspection of the pond was made by the hatchery staff. All dead fish found were recorded and the mark borne, or lack of mark was noted. It is possible that some fish died and were unobserved between daily inspections or were picked up by scavengers other than the large introduced trout.

Obviously the fish which died from causes other than predation should be eliminated from calculations. Thus to arrive at predator-caused mortality between any two dates, the survivors plus the known

TABLE 1.—Numbers of experimental lake trout fingerlings present in circular-pond experiment on October 6, 1949, and numbers of survivors at subsequent examinations.

Date	Normal fish	Marked fish			
		Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October 6, 1948.....	4,000	1,000	1,000	1,000	1,000
March 8, 1949.....	665	149	171	176	145
May 24, 1949.....	378	82	102	94	79
October 25, 1949.....	91	11	21	23	16

mortalities from other causes are subtracted from the numbers present at the prior date to determine the numbers of fish lost through predation in any time period. The observed mortalities for the circular pond experiment are shown in Table 2. By combination of the data in Tables 1 and 2, the numbers of fish of the various groups lost through predation may be calculated, and these calculations are given in Table 3.

TABLE 2.—*Observed mortalities and calculations on losses to predator fish in circular-pond experiment, October 6, 1948 to October 25, 1949.*

Date or item	Normal fish	Marked fish			
		Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October, 1948.....	27	5	11	5	4
November, 1948.....	3	3	2	7	2
December, 1948.....	1	1	2	12	2
January, 1949.....	1		2	4	2
February, 1949.....					
March, 1949.....					
Before March 8.....	4	2		2	
After March 8.....	11	2	2	5	2
April, 1949.....					
May, 1949.....	2			1	1
June–October, 1949.....					
Observed mortality.....	49	13	19	36	13
Alive at end.....	91	11	21	23	16
Known fate.....	140	24	40	59	29
Lost to predators or by other unknown means...	3,860	976	960	941	971

If a significantly larger number of marked than unmarked fish were lost to predators, then fin removal should be considered as a factor in analysis of recoveries from plantings of fin-clipped fingerling lake trout. Chi-square analysis was applied to the data in Table 3 to determine if the differences in numbers of fish lost to predators between marked and normal fish were of significant proportions. Adjusted chi-square values were calculated by the use of the formula given in Snedecor (1948, p. 197), utilizing the four-fold test of independence.¹

Chi-square values calculated for a comparison between normal fish and each mark used, at the March 8, 1949 and May 24, 1949 examinations, ranged between 0.13 and 2.47. Values for all normal fish compared with all marked fish were 0.29 and 0.06, respectively. When these values were referred to a chart of chi-square (prepared by C. E.

¹In a previous study on comparative mortality among fin-clipped and normal lake trout fingerlings (Shetter, 1951), the simplified chi-square test, as given by Snedecor (1948, Sec. 1.15), was utilized. Subsequently all calculations of this earlier study were redone, using the "test of independence" outlined by Snedecor (*op. cit.*, Sec. 9.6), which is regarded as a more sensitive chi-square test. The slightly higher chi-square values obtained do suggest that the normal fish had slightly higher survival rates than originally calculated, but the principal conclusions are not altered.

Bliss, Department of Pharmacology, Yale University), the percentage chance that the differences observed are significant ranged from 15 to 88.5, all below significant levels.

Chi-square calculations on the comparative losses between normal and marked fish between May 24 and October 25, 1949 were all non-significant, except for the dorsal-adipose group (chi-square = 3.92)

TABLE 3.—Numbers of lake trout fingerlings lost to predator fish between indicated dates, circular-pond experiment.

Date	Item	Normal fish	Marked fish			
			Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October 6, 1948	Number alive	4,000	1,000	1,000	1,000	1,000
March 8, 1949	Number alive	665	149	171	176	145
	Lost to predators	3,299	840	812	794	845
	Chi-square ¹	0.29	1.56	0.17	0.94	2.47
May 24, 1949	Number alive	378	82	102	94	79
	Lost to predators	276	65	67	75	63
	Chi-square	0.06	0.13	0.26	0.18	0.14
October 25, 1949	Number alive	91	11	21	23	16
	Lost to predators	285	71	81	72	63
	Chi-square	1.79	3.92	0.40	0.02	0.37
October, 1948 to October, 1949	Number alive	91	11	21	23	16
	Lost to predators	3,860	976	960	941	971
	Chi-square	2.12	4.95	0.03	0.00+	1.43

¹Chi-square values for comparison of normal and marked fish are given under "Marked fish." Under "Normal fish" the chi-square value given is based on a comparison between all normal fish and all marked fish.

where the value obtained was just barely over the 95 percent confidence level. For all normal fish compared with all marked fish for this same period, a non-significant value of 1.79 was obtained.

Over the course of the entire experiment, comparison of losses to predator fish among normal fish and the various groups of marked fish yielded non-significant values of chi-square for the right pectoral mark (0.03), left pectoral mark (0.00+), and the right pelvic mark (1.43). The significant value of chi-square computed for the dorsal-adipose mark (4.95) yields a percentage chance of 97.4 that this mark made these fish more vulnerable to predators. Over the period October 6 to October 25, 1949, comparison of losses to predators between normal fish and all marked fish yielded a non-significant value of chi-square (2.12) corresponding to an 85 percent confidence that the difference is significant.

GROWTH OF FISH IN THE CIRCULAR-POND EXPERIMENT

The average total lengths of the experimental fish used in the circular-pond experiment are given in Table 4, which lists the average total length, standard deviation, standard error, and size range of the various groups of fish at the start and at the later examinations. The averages are based on measurements of all fish present except at the initial examination, when a 12.5 percent sample was utilized because of the large number of fish involved. The growth data have been treated statistically to determine if significant differences in average length were present during the course of the experiment (Table 5).

The greatest difference in average lengths observed at any time was between normal fish and right pectoral-clipped fish at the start of the experiment in October, 1948 (2.31 mm.). This difference was significant ($t = 4.44$). The other groups of marked fish all had average sizes at the start slightly larger than the normal fish, but the statistical tests indicated the differences to be non-significant (t values ranged between 0.93 and 1.48). Grouping all marked fish together and comparing them with the normal fish at the initiation of the study, the marked fish were 0.11 millimeters smaller than the normal fish. The statistical tests indicated that this rather minute difference was significant ($t = 3.67$). At all other examinations there was no significant difference in average length between any single group of marked fish and normal fish, or between normal fish and all groups of marked fish combined (t values ranged between 0.04 and 1.55). In general, the experimental fish grew from about 62 millimeters in October, 1948 to approximately 154 millimeters in October, 1949.

The analysis of the average lengths of the survivors indicates that the marked fish in this experiment suffered no disadvantage as far as growth was concerned when compared with normal fish. The differences in average length between marked and unmarked survivors after the start of the experiment was demonstrated to be non-significant.

GROWTH OF THE PREDATOR FISH

The sizes of the predators at the start and at the various examination dates are given in Table 6. One brook trout died on November 4, 1948 and was not replaced. To assure that a reasonable number of survivors would be alive in October, 1949, the predators were reduced to one each of brook, brown, rainbow, and lake trout after the March, 1949, examination. One brook trout and one brown trout died and were replaced after the March, 1949, check.

The growth noted by measuring and weighing the large fish at each examination was not consistent, and there appears to have been some weight loss among the brook and brown trout, between October, 1948, and March, 1949, caused apparently by shedding of gonadal products.

TABLE 4.—The average size and numbers (in parentheses) of experimental lake trout examined at the four inspections, circular-pond experiment.

Date examined	Item ¹	Normal fish	Experimental group				
			Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	All marked fish
October, 1948	Average total length.....	62.16(500)	62.90(125)	59.85(125)	62.66(125)	62.77(125)	62.05(500)
	Standard deviation.....	5.18	4.91	5.21	5.48	5.75	5.48
	Standard error.....	0.23	0.44	0.47	0.49	0.51	0.25
	Size range in mm.....	44—73	50—73	47—74	46—73	39—73	39—74
March, 1949	Average total length.....	76.41(665)	75.65(149)	76.14(171)	76.23(176)	76.79(145)	76.20(641)
	Standard deviation.....	5.61	5.31	6.10	5.37	5.32	5.56
	Standard error.....	0.22	0.44	0.47	0.41	0.44	0.22
	Size range in mm.....	52—90	58—88	62—92	61—90	65—91	58—92
May, 1949	Average total length.....	95.04(378)	94.01(82)	94.97(94)	94.01(102)	95.47(79)	94.59(357)
	Standard deviation.....	7.93	8.68	9.14	13.23	7.87	10.12
	Standard error.....	0.41	0.96	0.94	1.31	0.89	0.54
	Size range in mm.....	69—115	75—115	76—118	78—111	81—108	75—118
October, 1949	Average total length.....	153.09(91)	154.45(11)	154.29(21)	154.52(23)	154.13(16)	154.35(71)
	Standard deviation.....	37.65	13.95	14.04	11.89	13.27	12.89
	Standard error.....	3.95	4.21	3.06	2.48	3.32	1.53
	Size range in mm.....	129—186	125—171	134—183	134—179	128—178	125—183

¹Formulae used throughout were:

$$M = \frac{\sum x}{n}$$

$$\text{Standard deviation} = \sqrt{\frac{\sum x^2 - (\sum x)^2}{n-1}}$$

$$\text{Standard error of } M = \frac{\text{Standard deviation}}{\sqrt{n}}$$

Also one rainbow trout appeared to lose in length as a result of injuries to his tail incurred in attempted spawning activities. The greatest gains noted were among the predator lake trout.

SPLIT-POND EXPERIMENT

The same general procedure was used in this experiment as in the study in the circular pond, except that five instead of three inspections were made during the 12 months. The additional inspections were undertaken 1 week after the start and 2½ months later in mid-January. Table 7 lists the numbers of experimental fish in the split pond at the

TABLE 5.—*Statistical comparisons of average total lengths of normal lake trout fingerlings with marked lake trout fingerlings at four inspections, circular-pond experiment.*

Date examined	Item ¹	Comparison of normal fish with				
		Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	All marked fish
October, 1948	Difference between average total length	0.74	2.31	0.50	0.61	0.11
	Standard error of difference	0.50	0.52	0.54	0.56	0.03
	<i>t</i> value	1.48	4.44	0.93	1.09	3.67
	Percentage chance	86	99 +	63	72	99 +
March, 1949	Difference between average total length	0.76	0.27	0.18	0.38	0.21
	Standard error of difference	0.49	0.52	0.46	0.49	0.31
	<i>t</i> value	1.55	0.52	0.39	0.78	0.68
	Percentage chance	88	39	32	56	50
May, 1949	Difference between average total length	1.03	0.04	1.03	0.43	0.45
	Standard error of difference	1.04	1.03	1.38	0.98	0.68
	<i>t</i> value	0.99	0.04	0.75	0.44	0.66
	Percentage chance	68	3	55	34	49
October, 1949	Difference between average total length	1.36	1.20	1.13	1.04	1.26
	Standard error of difference	5.77	5.00	4.66	5.16	4.24
	<i>t</i> value	0.24	0.24	0.24	0.20	0.30
	Percentage chance	19	19	19	16	23

¹Formulae used throughout were:

$$\text{Standard error of mean difference} = \sqrt{(\text{SE}_1)^2 + (\text{SE}_2)^2}$$

$$t = \frac{\text{Difference between means}}{\text{Standard error of difference}}$$

start, and the numbers of survivors found at subsequent inspections. The observed mortalities picked up from the split pond are recorded in Table 8, along with the calculated numbers of fish lost through predation.

As in the circular-pond experiment, combination of data on survival and observed mortalities makes possible the calculation of predation-caused mortalities between any two dates. Table 9 presents the calculations for the split pond, along with chi-square values which compare the losses of normal fish to losses of marked fish among the predation-caused deaths between any two dates.

In Table 9, the two significant values of chi-square occurred in comparisons between dorsal-adipose fish and normal fish. Removal of the dorsal and adipose fins apparently made fingerling lake trout more vulnerable to predator fish between October 5 and October 11, 1948

TABLE 6.—*Growth history of the predator fish in the circular-pond experiment. Lengths (L) are given in millimeters, weights (W) in pounds.*

Date checked	Brook trout ¹		Brook trout ²		Brown trout		Brown trout ³		Rainbow trout		Rainbow trout		Lake trout		Lake trout	
	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
October, 1948	355	1.30	335	1.20	520	4.30	516	4.60	460	2.90	538	4.40	490	2.50	470	2.10
March, 1949	.....	.....	350	1.10	520	3.75	516	3.50	500	3.00	529	4.00	520	2.50	520	2.80
May, 1949	.....	.....	384	1.83	.....	.....	514	3.97	.....	.....	541	4.25	.....	.....	541	3.88
October, 1949	.....	.....	397	1.88	.....	.....	470	3.00	.....	.....	579	4.75	.....	.....	578	3.50

¹Died November 4, 1948, at 356 millimeters, 1.25 pounds.

²Died March 24, 1949, at 350 millimeters, 1.10 pounds; replaced April 5, 1949 by brook trout of 368 millimeters, 1.50 pounds.

³Died May 24, 1949, at 514 millimeters, 3.97 pounds; replaced same day with brown trout of 397 millimeters, 1.75 pounds.

(chi-square = 16.05) in the pond with no cover. In the same pond and for comparisons of the same two groups of fish, a significantly greater loss of dorsal-adipose fish occurred between March 9 and May 24, 1949 (chi-square = 7.63). However, all other chi-square values calculated for the other fin combinations and periods involving the pond without cover are small and non-significant (or in one instance the value is significant and in an opposite direction).

In the pond with cover, losses of marked fish, when compared with losses of normal fish to the introduced predators, were no more than were to be expected by chance selection. Only in one instance (right pelvic mark, between October 11, 1948 and January 17, 1949) was there a significant value for chi-square (4.76), and that involved better survival of marked fish. For all other comparisons, chi-square values were non-significant, ranging from 0.00+ to 3.63.

All comparisons for the entire period of the experiment yielded non-significant chi-square values.

THE EFFECT OF COVER

To test the effect of cover, chi-square analysis was employed on the losses to predators in the pond with cover and without cover for marked fish only and also of all fish combined. This was done for each examination and also for the final results. The data on this point are summarized in Table 10.

For both sets of comparisons there were significantly fewer mortalities in the pond with cover up to January 17. Between January 17 and March 9, there were significantly fewer mortalities due to preda-

TABLE 7.—Numbers of lake trout fingerlings present in the split-pond experiment on October 4, 1949, and numbers of survivors at subsequent examinations.

Date	Pond with no cover					Pond with cover				
	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October 4, 1948.....	500	125	125	125	125	500	125	125	125	125
October 11, 1948.....	471	105	122	116	116	474	121	117	122	115
January 17, 1949.....	223	46	56	51	56	319	78	89	83	89
March 9, 1949.....	168	35	48	39	42	259	59	70	65	66
May 24, 1949.....	72	6	20	14	21	200	43	52	43	49
October 25, 1949.....	10	0	2	1	2	79	15	18	23	22

TABLE 8.—*Observed mortalities and calculations on losses to predator fish in split-pond experiment, October 4, 1948, to October 25, 1949.*

Date or item	In pond with no cover					In pond with cover				
	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October, 1948	8	2	2	2	.....	1	1	0	.....	1
Before October 11.....	3	2	1	3	.....	10	.....	2	.....	1
After October 11.....										
November, 1948.....			1	.....	.....	.....	.....	1	.....	.....
December, 1948.....	1	.....	1	.....	.....	.....	.....	.....	1	.....
January, 1949										
Before January 17.....	6	6	1	4	1	13	4	1	4	4
After January 17.....										
February, 1949.....										
March, 1949										
Before March 9.....	3	.....	.....	2	2	4	.....	.....	3	.....
After March 9.....	8	1	.....	.....	.....	4	2	1	.....	.....
April to October, 1949.....										
Observed deaths.....	29	11	6	11	3	32	7	5	8	6
Known survivors.....	10	0	2	1	2	79	15	18	23	22
Known fate.....	39	11	8	12	5	111	22	23	31	28
Loss by predation.....	461	114	117	113	120	389	103	102	94	97

TABLE 9.—Numbers of lake trout fingerlings lost to predator fish between indicated dates, split-pond experiment. (*Chi-square values for comparison between marked and normal fish are given under the marks listed. Under "Normal fish" the chi-square values given are for comparison between all marked and all normal fish.*)

Date and item	Pond without cover					Pond with cover				
	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip
October 4, 1948										
Alive.....	500	125	125	125	125	500	125	125	125	125
October 11, 1948										
Alive.....	471	105	122	116	116	474	121	117	122	115
Lost.....	21	18	0	8	9	25	4	8	3	10
Chi-square.....	3.14	16.05	4.17	0.62	1.27	0.02	0.39	0.16	1.04	1.17
January 17, 1949										
Alive.....	223	46	56	51	56	319	78	89	83	89
Lost.....	238	51	63	57	59	132	38	24	34	20
Chi-square.....	0.03	0.00+	0.02	0.01	0.00+	1.44	0.38	2.53	0.01	4.76
March 9, 1949										
Alive.....	168	35	48	39	42	259	59	70	65	66
Lost.....	52	11	8	10	12	56	19	19	15	23
Chi-square.....	0.62	0.02	1.77	0.08	0.00+	2.07	1.35	0.37	0.00+	2.38
May 24, 1949										
Alive.....	72	6	20	14	21	200	43	52	43	49
Lost.....	88	28	28	25	21	55	14	17	22	17
Chi-square.....	1.62	7.63	0.06	0.72	0.16	1.93	0.10	0.15	3.63	0.32
October 25, 1949										
Alive.....	10	0	2	1	2	79	15	18	23	22
Lost.....	62	6	18	13	19	121	28	34	20	27
Chi-square.....	0.58	0.12	0.01	0.06	0.02	0.01	0.15	0.24	2.30	0.28
October 4, 1948 to October 25, 1949										
Alive.....	10	0	2	1	2	79	15	18	23	22
Lost.....	461	114	117	113	120	389	103	102	94	97
Chi-square.....	1.06	1.36	0.00+	0.24	0.00+	0.08	0.93	0.13	0.33	0.08

tion in the pond without cover. Between March 9 and May 24, the pond with cover had significantly fewer deaths as a result of predation, but between May 24 and October 25 the situation was reversed again. If all mortalities (either among marked fish, or all fish combined) are compared from the two enclosures, there were significantly fewer mortalities as a result of predation in the pond with cover.

HISTORY OF PREDATORS IN THE SPLIT POND

It is necessary to consider the course of predation in this experiment closely. To satisfy experimental conditions, both ponds should have been subjected to the same amount of predation if all conditions except the factor of cover were to be equal. Despite our efforts the amount of predation was not always equal in the two ponds (Table 11).

TABLE 10.—*Comparative losses to predation of all marked fish, and all fish in pond with cover and pond with no cover (with chi-square values for periods between the indicated dates).*

Date and item	Marked fish			All fish		
	No cover	Cover	Chi-square	No cover	Cover	Chi-square
October 4, 1948						
Alive.....	500	500	.....	1,000	1,000	.....
October 11, 1948						
Alive.....	459	475	.....	930	949	.....
Lost to predators.....	35	25	1.55	56	50	0.32
January 17, 1949						
Alive.....	209	339	.....	432	658	.....
Lost to predators.....	230	116	67.01	468	248	113.42
March 9, 1949						
Alive.....	164	260	.....	332	519	.....
Lost to predators.....	41	76	0.37	93	132	0.31
May 24, 1949						
Alive.....	61	187	.....	133	387	.....
Lost to predators.....	102	70	50.07	190	125	98.35
October 25, 1949						
Alive.....	5	78	.....	15	157	.....
Lost to predators.....	56	109	21.73	118	230	37.05
October, 1948 to October, 1949						
Alive.....	5	78	.....	15	157	.....
Lost to predators.....	464	396	67.45	925	785	126.89

Between October 5 and October 11, 1949, a rock bass was present in the pond with cover. This fish had escaped observation at the initiation of the experiment. Also in the pond with cover the predatory lake trout apparently was removed by some unknown agent and at some unknown date between October 11 and January 17. In this same pond the brook trout predator died in late March and was not replaced for 11 days.

TABLE 11.—*Growth history of predator fish in the split-pond experiment. Lengths (L) are given in millimeters, weights (W) are given in pounds. The numbers of predator-days are given in parentheses.*

Date	Predators in pond without cover						Predators in pond with cover					
	Brown trout ¹		Yellow pike-perch ¹		Lake trout ²		Brook trout		Brown trout ¹		Yellow pike-perch ¹	
	L	W	L	W	L	W	L	W	L	W	L	W
October 5, 1948	345	0.75 (6)	549	3.20 (6)	310	 (3)	.....	.....	259	0.50 (6)	510	2.25 (6)
October 11, 1948	345	0.75	549	3.20	310	 (98)	310	 (98)	259	0.50	510	2.25
January 17, 1949	.....	.....	.....	.....	330	0.62 (51)	315	0.75 (51)	.....	.....	.....	.....
March 9, 1949	.....	.....	.....	.....	336	0.61 (76)	321	0.72 (76)	.....	.....	.....	.....
May 24, 1949	.....	.....	.....	.....	340	0.67 (?)	335	0.77 (154)	.....	.....	.....	.....
October 25, 1949	.....	..... (6)	.....	.....	.....	.....	362	1.31 (379)	.....	..... (6)	433	1.56 (284 +?)
												 (6)

¹These fish removed October 11, 1948.

²These fish put in October 8, 1948.

³This fish disappeared sometime between May 24, 1949 and October 25, 1949.

⁴This fish disappeared sometime between October 11, 1948 and January 17, 1949, and another of the indicated size put in on January 17, 1949.

⁵This fish died April 24, 1949 at a size of 339 millimeters, 1.12 pounds. It was replaced on April 5, 1949 with a brook trout of 368 millimeters, 1.32 pounds.

All predators were present in the pond with no cover between October 5, 1948 and May 24, 1949. Sometime between the latter date and October 25, 1949, the predatory lake trout was removed, as there was no evidence of this fish when the experimental pond was finally drained.

During the first week of confinement, no advantage can be demonstrated for cover (chi-square values insignificant; marked fish, 1.55; all fish, 0.32). At the January and May examinations, where chi-square values suggested that cover was a favorable factor, it was found that one predator fish had been missing from the pond with cover in the period immediately preceding the examination for an unknown length of time. Failure to maintain an equal number of predators in both ponds at all times may have influenced the observed results. For the course of the entire experiment, however, it can be shown that the pond with cover was subjected to a slightly greater number of predator-days (670 observed predator-days as against 619 for the pond without cover). The measurements on the predators at the various inspections indicated that growth was more regular and of a more positive nature than was observed in the circular-pond experiment.

GROWTH OF LAKE TROUT IN SPLIT POND

The average total lengths (in millimeters) along with the standard deviation and the standard error are given in Table 12 for each group of experimental fish in the two parts of the split pond. The survivors were measured on four different dates after the start of the experiment. The "*t*" test was employed to determine if the differences in average length between marked fish and normal fish were significant. The results of the statistical analyses are contained in Table 13.

DISCUSSION

The results obtained, in both the large-scale experiment in the circular pond and the two small-scale tests in the split pond, yield the same conclusions: (1) that fin removal did not increase losses of marked fingerling lake trout to predatory fish to any greater degree than might be expected on a basis of chance selection, and (2) that the marking process did not cause any retardation of growth of the marked lake trout fingerlings so exposed.

It might be argued that the dorsal-adipose fish in the circular-pond experiment were adversely affected by the marking process and were significantly more vulnerable to predation. However, dorsal-adipose fish in the split-pond experiments were not found to be significantly more subject to predation than normal fish, according to the chi-square calculations for the entire year of observation. None of the chi-square calculations showed any consistent trend that indicated that marked fish were at a disadvantage as far as being more subject to predation than were normal fish. Chi-square values determined for the comparison

TABLE 12.—The average size and numbers (in parentheses) of experimental lake trout fingerlings examined at various dates, split-pond experiment. Size range is given in millimeters.

Item	Pond without cover					Pond with cover				
	Normal fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	Normal fish	Dorsal-adipose clip	Left pectoral clip	Right pectoral clip	Right pelvic clip
October, 1948										
Mean.....	59.86(500)	59.40(125)	61.30(125)	61.03(125)	61.05(125)	61.41(500)	63.17(125)	63.19(125)	62.66(125)	64.03(125)
S.D.....	5.39	3.97	5.04	5.62	5.40	4.94	4.76	4.38	5.48	4.93
S.E.....	0.24	0.53	0.45	0.50	0.48	0.22	0.43	0.39	0.25	0.44
Size range.....	45—72	47—72	44—73	46—74	44—72	50—72	50—75	52—73	50—73	52—77
January, 1949										
Mean.....	70.52(223)	70.35(46)	72.00(56)	71.41(51)	71.45(56)	74.84(319)	76.12(78)	75.96(89)	76.69(83)	76.89(89)
S.D.....	5.05	6.13	3.69	6.43	3.34	5.19	5.22	4.49	4.40	5.60
S.E.....	0.34	0.90	0.49	0.90	0.45	0.29	0.19	0.48	0.48	0.59
Size range.....	54—81	55—79	62—81	58—81	58—81	62—86	64—93	65—87	63—84	65—94
March, 1949										
Mean.....	73.15(168)	73.86(35)	74.65(48)	75.13(39)	74.83(42)	77.49(259)	78.61(59)	78.63(70)	79.71(65)	79.32(66)
S.D.....	3.47	3.75	3.91	5.68	3.64	5.15	5.31	4.85	4.32	5.83
S.E.....	0.27	0.64	0.56	0.91	0.56	0.32	0.69	0.58	0.54	0.72
Size range.....	57—84	67—83	65—82	62—87	61—84	65—91	67—94	67—91	68—88	66—97
May, 1949										
Mean.....	82.88(72)	80.00(6)	83.70(20)	80.71(14)	85.48(21)	91.01(200)	93.91(43)	92.42(52)	92.60(43)	94.53(49)
S.D.....	5.45	7.62	5.61	5.24	6.09	7.88	6.77	5.97	6.01	7.36
S.E.....	0.64	3.11	1.25	1.40	1.33	0.56	1.03	0.83	0.92	1.05
Size range.....	68—98	66—87	72—93	72—93	72—98	75—110	84—110	80—103	80—104	76—111
October, 1949										
Mean.....	118.90(10)	.....	126.00(2)	121.00(1)	127.00(2)	139.47(79)	149.07(15)	141.56(18)	141.22(23)	143.82(22)
S.D.....	13.52	.....	2.00	0.00	15.56	12.79	11.68	12.43	11.09	11.97
S.E.....	4.28	.....	1.41	0.00	11.00	1.44	3.02	2.93	2.31	2.55
Size range.....	98—140	.....	125—127	121	116—138	110—168	133—168	111—173	111—157	111—164

TABLE 13.—Statistical comparison of average total lengths of normal and marked lake trout fingerlings at various inspections, split-pond experiment. (See footnotes in Table 5 for formulas and procedures.)

Item	Pond without cover—comparison of normal fish with					Pond with cover—comparison of normal fish with				
	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	All marked fish	Dorsal-adipose clip	Right pectoral clip	Left pectoral clip	Right pelvic clip	All marked fish
October, 1948										
Diff.....	-0.46	+1.44	+1.17	+1.19	+0.84	+1.76	+1.78	+1.25	+2.62	+1.85
S.E.....	0.58	0.51	0.65	0.54	0.35	0.48	0.45	0.33	0.49	0.31
t.....	0.79	2.82	2.13	2.20	2.40	3.67	3.96	3.79	5.35	5.97
Percentage.....	57	99	97	97	98	100	100	100	100	100
January, 1949										
Diff.....	-0.17	+1.48	+0.89	+0.93	+0.82	+1.28	+1.12	+1.85	+2.05	+1.58
S.E.....	0.96	0.60	0.96	0.56	0.49	0.35	0.56	0.56	0.66	0.40
t.....	0.18	2.47	0.93	1.66	1.67	3.66	2.00	3.30	3.11	3.95
Percentage.....	14	98	64	90	91	100	95	100	100	100
March, 1949										
Diff.....	+0.71	+1.50	+1.98	+1.68	+1.49	+1.12	+1.14	+2.22	+1.83	+1.60
S.E.....	0.69	0.62	0.95	0.62	0.43	0.76	0.66	0.63	0.79	0.45
t.....	1.03	2.42	2.08	2.71	3.47	1.47	1.73	3.52	2.32	3.56
Percentage.....	70	98	96	99	100	86	92	100	98	100
May, 1949										
Diff.....	-2.88	+0.82	-2.17	+2.60	+0.38	+2.90	+1.41	+1.59	+3.52	+2.35
S.E.....	3.18	1.40	1.54	1.48	1.05	1.17	1.00	1.08	1.19	0.74
t.....	0.91	0.59	1.41	1.76	0.36	1.48	1.41	1.86	2.96	3.18
Percentage.....	63	43	84	92	28	86	84	86	99	99
October, 1949										
Diff.....	.....	+7.10	+2.10	+8.10	+6.50	+9.60	+2.09	+1.75	+4.35	+4.07
S.E.....	.....	4.51	4.28	11.80	5.63	3.35	3.26	2.72	2.93	1.97
t.....	.....	1.57	0.49	0.69	1.15	2.87	0.64	0.64	1.48	2.07
Percentage.....	.....	88	38	51	1.75	100	48	48	86	96

of losses to predation of all marked fish and normal fish were non-significant in all three experiments over the entire year of observations.

Because predation was not maintained in equal amounts at all times in the ponds with cover and without cover, clear-cut results were not obtained concerning the effect of cover on the mortality of marked fingerling lake trout. However, total results suggest that cover very likely is a favorable factor in keeping mortality from predation at a lower level than in situations where no cover is present.

These experiments, although conducted under habitat conditions very unlike the natural haunts of fingerling lake trout, intimate strongly that the marked fish released in the Great Lakes have not suffered greater mortalities as a result of predation than have the unclipped lake trout fingerlings planted at the same time.

ACKNOWLEDGMENTS

I wish to thank Russell Robertson, Hatchery Supervisor, and his staff of the State Fish Hatchery, Marquette, Michigan, for assistance received in handling the experimental fish, recording mortalities, and other aid as the need arose. Dr. L. N. Allison, Fish Pathologist, Stanley Lievense, District Fisheries Supervisor, and R. F. Stinauer, Fisheries Technician, assisted me at various times with the sorting and recording. I am grateful for their help.

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SURVIVAL OF HATCHERY-REARED CUTTHROAT TROUT IN AN ALBERTA STREAM

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ABSTRACT

Gorge Creek, a typical small mountain trout stream in southwestern Alberta, was divided by fish-tight screens into two sections, each about three-quarter miles in length. The number of native trout in these was determined by marking and recapture. One section was left as a control. Into the other, 199 3-year-old and 201 2-year-old hatchery-reared cutthroat trout were liberated. Each of the planted trout was weighed and given a numbered Petersen tag before planting. Fish that died were removed daily and weighed. Daily angling was carried on to recapture, weigh, and again release as many as possible. One-third of the 3-year-old fish died, mainly in the first 2 weeks following planting. All lost weight for 40 days, apparently through inability to compete with the native population. By fall (about 100 days after planting) the survivors had regained their planted weights. All, or nearly all, of the 2-year-old fish died, apparently from a combination of shock and starvation. The native trout in the experimental section gained weight all summer and, by fall, were in as good condition as the native trout in the control section.

Plans for planting hatchery-reared trout in sections of stream free of native trout, and for transplanting native trout into sections containing native trout are described.

INTRODUCTION

Over the past 15 years a great deal of work has been done on the survival of hatchery-reared trout, both in streams and in lakes. This work has been reviewed recently (Smith, 1948; Miller, 1949) and need not be given detailed reference here. With a few exceptions, it has been found that trout planted in streams which already contain trout fail to survive. This result is particularly true where the planted trout are of the same species or have the same habits as the existing population. As a result of these findings, in areas where fishing pressure is great, the practice is to plant legal-sized trout during the open season with the idea that they will be caught by anglers before winter. Those that are not caught are presumed to be lost. The cost of raising legal-sized trout is high and is materially increased if fish planted and not caught are excluded when cost per fish is reckoned. As Schuck (1948) has pointed out, it is desirable to determine why these hatchery fish do not survive and to seek a remedy in modified rearing procedures. Schuck (op. cit.) has thoroughly reviewed the pertinent literature. Needham *et al.* (1945) showed that mortality in mountain trout streams was normally very high (60 percent per annum) and affected wild as well as hatchery fish. Failure of hatchery trout to survive is, therefore,

partially a natural phenomenon. However, Needham and Slater (1944) and Schuck (op. cit.) have shown that this annual mortality is significantly higher in hatchery trout and the former authors have published evidence that the lower survival is due, at least partly, to competition with wild trout in the stream.

The experiment described in the present paper is the first of a series planned to throw more light on the mortality of hatchery-reared trout. The work forms part of the programme of the Alberta Biological Station, operated jointly by the University of Alberta and the Fisheries Branch of the Province of Alberta. The plan of the experiments calls for testing the survival of legal-size and larger cutthroat trout, planted in screened-off sections of a stream. The first year's work tested survival of planted fish in competition with native wild trout and is reported here. The experiment differs from others with which the author is familiar in that all planted trout are tagged and weighed before planting.

EXPERIMENTAL AREA

Gorge Creek was chosen for the experiment because it is a typical trout stream of the eastern slopes of the Rocky Mountains. The creek rises at approximately 6,000 feet and descends about 8 miles to enter the Sheep river at 4,800 feet. The average gradient is 150 feet per mile. The stream varies from 3 or 4 to 30 feet in width and forms a succession of gravelly riffles and rocky pools as it flows through a deep shale canyon. In May and June, during the run-off it flows at 7 miles per hour, but in summer the flow is about 1.5 to 2.0 miles per hour. Temperatures throughout the open season vary from 33° F. to 67° F. with daily summer temperature variations of 14° F. to 16° F. For example, a typical summer-day minimum is 48° F. and the maximum the same day, 63° F. The volume of bottom fauna is approximately 0.5 cubic centimeters per square foot. Gorge Creek contains a large population of native cutthroat trout estimated at 500 to 600 catchable fish per mile.

EXPERIMENTAL PROCEDURE

Fish-tight screens made from wooden frames covered with chicken wire netting and pound net twine were erected at three places in Gorge Creek to create two enclosures, each approximately three-quarters of a mile in length. Enclosure 1 was the experimental section and enclosure 2 was used as the control. In both enclosures a marking experiment was conducted to determine the number of wild trout present. Trout were caught by angling, fin-clipped and released and the following estimates made:

Enclosure 1—104 trout marked, population 290

Enclosure 2— 89 trout marked, population 260

On June 16, 1950, 199 3-year-old cutthroat trout were released in enclosure 1. Each of these bore a numbered Petersen tag of red plastic and all appeared to be in good condition. Each fish was weighed to the nearest half ounce the day before planting and the tag number and weight recorded. These fish ranged from 3.5 to 11 ounces in weight and from 12 to 15 inches in fork length. On July 5, 1950, 201 2-year-old cutthroat trout were planted in enclosure 1. They were tagged and weighed in the same manner as the first group. The fish ranged from 1.5 to 3.5 ounces in weight and from 5 to 8 inches in fork length.

From the time of the plantings until September 22, 1950, fish were caught from both enclosures by angling. The tagged fish were weighed and released after their tag numbers were noted. In this way 142 of the 3-year-old fish and 124 of the 2-year-olds were recaptured and reweighed, some several times, throughout the summer. Wild trout from both enclosures were taken periodically, weighed and measured, and their condition factors calculated. Hatchery trout which died and drifted against the screens provided similar data for the hatchery group.

The lowermost screen was maintained in position until April 28, 1951, on which date it washed out in a flood. It was reinstalled on May 11, but floods persisted until July 19 and the screen was in and out erratically during May and June. Thus the hatchery fish were forced to remain where they were planted for nearly 1 year. After this period some of the survivors could have migrated out but, as will be shown below, the numbers are not significant.

MORTALITY OF HATCHERY FISH

Three-year-old trout.—On the day after planting the majority of the 199 3-year-old fish was congregated above the downstream screen of the enclosure although 136 of them had been released at the upper end. There is no doubt that most of them would have drifted downstream and out of Gorge Creek altogether had the screen not been present. On the second day dead fish began drifting against the screen. By the twentieth day 23.1 percent had been picked off the screen. Fish continued to die until the forty-fourth day by which time 30.1 percent had been found dead. During this time one wild trout was found dead.

Two-year-old trout.—This group also collected above the screen and would have left Gorge Creek if it had been possible. They began dying on the day after planting; by the fourteenth day 46.8 percent had died. Mortality continued at a greatly reduced rate until the eighty-fifth day. A total of 113 fish, or 56.2 percent, was picked up dead.

Hidden losses.—After the first few weeks both groups of planted fish ceased schooling in front of the lower screen and spread upstream, behaving more like wild fish. Since dead fish thrown in the upper end of the enclosure did not drift as far as the lower screen, some hatchery

fish may have died and failed to drift as far as the screen. There is probably, therefore, some unmeasured mortality. This loss was increased by a violent hailstorm on August 10, which caused the blocking of the screens and a flow of water around their ends. For a few hours, fish had opportunity of escaping from the enclosures. The size of this hidden loss was measured by comparing the catches of hatchery trout to catches of wild trout in the same enclosure; i.e., after mid-August, the hatchery fish had become as difficult to catch as the wild fish so that the ratio of hatchery to wild fish caught should be the same as the ratio of their abundance. For the 3-year-old trout, the figure obtained by such a comparison indicated that hidden loss had been insignificant. For the 2-year-old trout, the recorded mortality of 56.2 percent proved to be too small. The ratio of 2-year-old hatchery fish to wild trout caught indicated that only about 30 2-year-olds remained in the stream. Thus the true mortality was around 85 percent.

That mortalities of 30 percent and 85 percent for the two lots of fish are substantially correct was easily determined by walking up the stream. The water is very clear and the red and white discs on the hatchery fish made them readily visible. After mid-August very few of the small hatchery fish were seen.

Over-winter survival.—Angling has been carried out by the staff of the Biological Station almost daily in Gorge Creek from June through September, 1951. No 2-year-old hatchery trout have been seen or caught and four of the 3-year-olds have been caught. Three of these latter fish were taken in Sheep River, below Gorge Creek. The over-winter survival of 2-year-old trout is apparently zero. In 3-year-old trout it is somewhere between 2 percent and 70 percent but, evidently, much closer to the small end of the range. It is certain that only two or 1 percent of the plant survived in Gorge Creek.

TABLE 1.—Weights of hatchery-reared fish taken after planting in Gorge Creek and expressed as a percentage of planted weight.

Tag number	First check		Second check		Third check		Fourth check	
	Day	Weight	Day	Weight	Day	Weight	Day	Weight
293	14	90	78	100				
312	31	78	43	71				
325	42	117	93	133				
328	22	82	48	91				
373	11	86	90	75				
231	10	100	39	83	52	75		
343	33	80	38	80	68	80		
344	21	75	23	72	70	53		
378	26	78	46	82	64	93		
393	12	71	26	64	68	57		
289	33	114	49	143	64	135	85	114

WEIGHT RECORDS OF PLANTED FISH

Fish that died were taken off the screen daily, weighed, counted, and examined for stomach contents. As previously stated, fish were also caught by angling (with artificial flies tied on small hooks), weighed and released. In Table 1 the records of a number of fish which were weighed more than once after planting are shown.

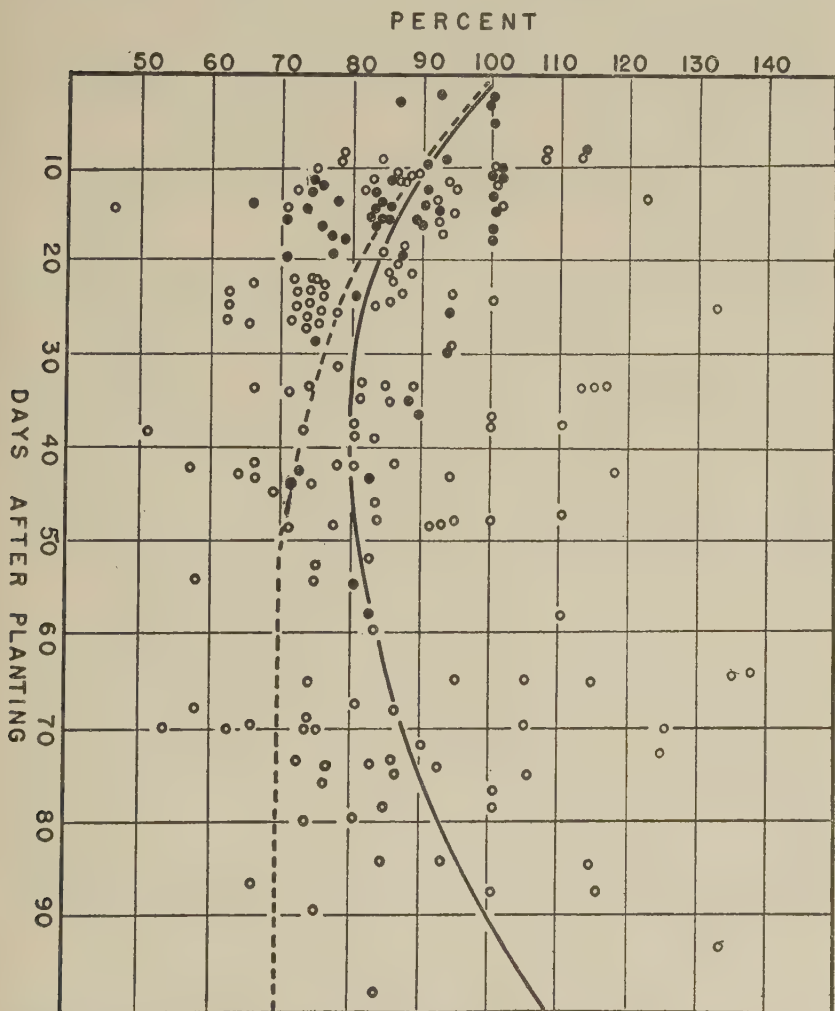


FIGURE 1.—Weight change of 3-year-old trout after planting in Gorge Creek. The continuous curve is drawn through the average percentage of planted weight for each 10-day interval. The broken curve represents survival. Open circles are fish released after weighing; closed circles are fish weighed after death.

The individual records shown in Table 1 give some idea of the trend in weight change of the planted fish. Of the eleven fish, two gained weight and nine lost weight. A more comprehensive appraisal is obtained by including fish which were only caught once for a weight check and fish which died and were weighed within 24 hours. These data have been grouped into 10-day intervals and the average percentage of planted weight for each interval calculated. Figure 1 has been drawn to express the results graphically for the 3-year-old trout and Figure 2 for the 2-year-old trout. In both figures the continuous curve is drawn through the 10-day average points, while the open and closed circles represent individual fish. Open circles are fish which were released alive after weighing and closed circles are fish weighed after dying. The solid curves give a continuous record of weight change with time while the broken curves on the same figures indicate survival with time.

On the average, the 3-year-old trout lost 20 percent of their weight during the 40 days following planting (Figure 1). They then began to gain and, by 92 days, had regained their planted weight. It is interesting and, perhaps, significant that mortality ceased at the same time as the fish began to gain weight (between 40 and 50 days after planting). With three exceptions, the stomachs and intestines of fish which were picked dead off the screen were empty.

The 2-year-old trout fared much worse than the 3-year-olds (Figure 2). Their average weights fell to less than 65 percent of planted weight by the thirtieth day. Thereafter recaptures were too few to yield significant results. With no conspicuous gain in weight it is not surprising that mortality continued and that survival appears to have been zero.

EFFECT OF HATCHERY TROUT ON WILD TROUT

During May and June the average condition factor (K) of the wild trout in enclosure 1 (with hatchery trout) was 0.88, and in enclosure 2 it was 0.90. These means were not significantly different. In August the wild trout in enclosure 1 had an average condition factor of 0.98 and the trout in enclosure 2, 1.02. In both enclosures the wild fish came through the winter and into spring in a relatively poor condition. They gained weight during the summer and were fat and ready for winter again by fall. The presence of the hatchery trout in enclosure 1 does not seem to have affected materially the wild trout since they gained as much weight as the wild trout in enclosure 2.

CAUSE OF MORTALITY

The record of the weight changes suggests that the planted fish died of starvation; they did not begin eating for about 40 days and lost weight during this period. Furthermore, mortality ceased when feeding began. The failure to feed in the first 40 days is due partly to compe-

tition with wild trout. On many occasions a tagged trout was observed to start out after a morsel in the current, only to be turned aside and the food taken by a wild trout. The disappearance of the whole planting of 2-year-old fish can probably be ascribed to unsuccessful competition leading to starvation. However, about 30 percent of the 3-year-olds and half the 2-year-olds died too soon after planting to have starved. Also, many died before losing a significant amount of weight. These early deaths must be due to the change in environment from the rearing pond to the stream. Observation suggests that the stream

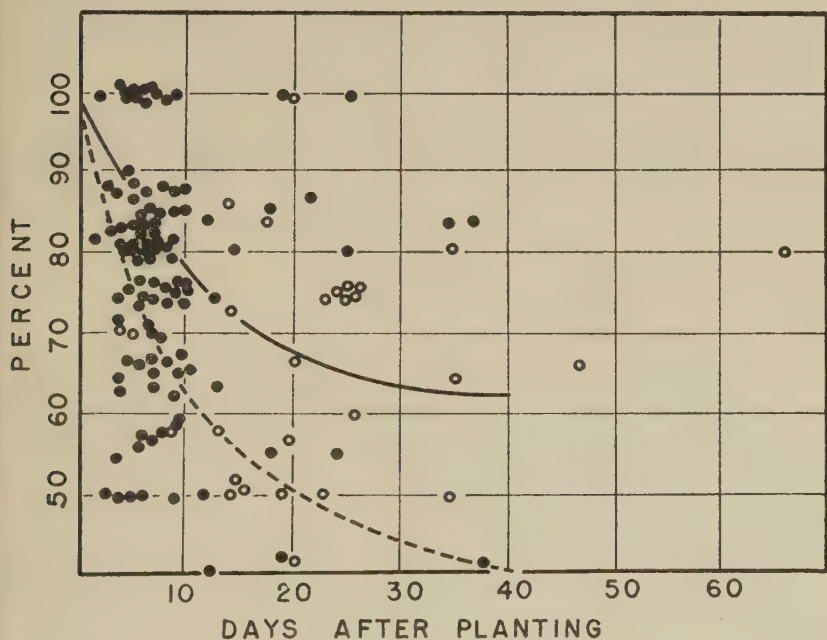


FIGURE 2.—Weight change of 2-year-old trout after planting in Gorge Creek.
Explanation same as Figure 1.

current is the major factor. The planted trout drifted with the current for at least 2 weeks and seemed unable to maintain a position in the stream. It is probable that initial deaths were from exhaustion. In summary, we have two possible causes of mortality. The first is early death through exhaustion, and second, later deaths from starvation due to inability to compete with wild trout. The large 3-year-old trout were much less affected by the second cause since they were bigger than the wild trout in the stream.

CONCLUSIONS

Cutthroat trout planted in east slope tributary streams probably do not remain in the tributaries but drift downstream for about 2 weeks after planting. Mortality during this period of drifting is apparently due to exhaustion. In the experiment described here this mortality amounted to approximately 30 percent of 3-year-old trout and about 50 percent of 2-year-old trout. Fish which survive this initial period of adjustment to physical stream conditions suffer further mortality from starvation. Three-year-old planted trout learned to feed in about 40 days. By fall they had regained their initial weights but were not in condition to stand winter conditions. Two-year-old trout disappeared almost entirely before freeze-up apparently from starvation. Wild trout in the stream were little affected by the hatchery fish.

ACKNOWLEDGMENTS

I am indebted to Mr. U. M. Mangan, who was in charge of the field work, and who worked up much of the data; and to Mr. M. J. Paetz, who assisted Mr. Mangan in the field.

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RESULTS FROM STOCKING BROOK TROUT OF WILD AND HATCHERY STRAINS AT STILLWATER POND

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ABSTRACT

In 1948 and 1949, 1,000 fingerling brook trout of a wild strain and 4,500 fingerlings of a hatchery-developed strain were stocked in Stillwater Pond, a 55-acre pond in Putnam County, New York. All fingerlings were fin-clipped for recognition. Returns from plantings in both years followed similar patterns. Yields from the wild strain were disproportionately low in the first season after planting and disproportionately high in the second season. Field observations indicated that individuals of the two groups were consistently different in appearance and generally could be separated by characteristics of body shape and color. Length-weight data, expressed as condition factors, illustrate morphological differences in trout of the two groups after they had been in the pond for 18 months. Angling returns indicate that better angler satisfaction may be obtained here from stocking trout of both strains together than from stocking either one alone. It is concluded that differences in these two strains of trout as exhibited in this situation are hereditary (racial) and are of sufficient magnitude to be important in management of a brook trout fishery.

INTRODUCTION

Among fisheries workers there has been less concern about intra-specific hereditary characteristics of fish than there has been among agriculturalists, horticulturists, and dog fanciers in the pedigrees of animals and plants. It is true that experts among European carp culturists have long recognized the importance of physiological races of carp with relation to rearing them successfully in ponds (Schaeperclaus, 1933). In general, the importance of intra-specific racial characteristics of game fishes, including trout, is a topic often mentioned but seldom given active attention.

A few authors have exhibited a continuing interest in racial characteristics of trout but most investigations in this field have been concerned with improvement of hatchery production. White's work (1930, 1934) is especially interesting because it was concerned primarily with the significance of variations among populations or races of wild trout. A paper by Haskell (1952) gives a painstaking comparison of the growth rates under hatchery conditions of three strains of wild lake trout.

The common occurrence of local varieties of wild brook trout is widely recognized. Also, most fish-culturists tacitly recognize the plasticity of the species by their handling of hatchery developed strains. For various reasons, testing the stability and general usefulness of

wild strains of trout when they are stocked in wild waters has been difficult. It is the purpose of this paper to contribute evidence regarding the stability and individual characteristics of two strains of brook trout, one of them derived from a wild population, and to emphasize the potential importance of intra-specific variations of characters in trout to trout management.

A primary handicap to experimental work with different strains of trout in wild waters has been the difficulty of checking results. At Stillwater Pond in Clarence Fahnestock Memorial Park, Putnam County, New York, a complete record of the catch has been kept since fishing began there in 1945. This pond has provided an unusual opportunity for testing various details of trout management. Therefore, when a wild stock of brook trout became available, it was decided to test its characteristics at this pond in comparison with an extensively used hatchery stock.

CHARACTERISTICS OF STILLWATER POND

Stillwater is an artificial headwater pond of 55 acres located just 50 miles north of Times Square, New York City. It lies at an elevation of approximately 860 feet above sea level, but is surrounded by hills which have elevations up to 1,300 feet. The maximum depth is 30 feet near the dam with about half the area having a depth of 20 feet or more. The inlet shrinks to a few gallons per minute in dry weather but has not been seen completely dry. A beaver dam has been continuously maintained immediately above pond level on the inlet.

Temperature and chemical conditions of the pond are generally considered unfavorable for trout. The analysis for the deep-water station made July 17, 1951 is given in Table 1. Oxygen values appear to be slightly more favorable for trout in 1951 than they were in 1942. Bottom samples had a strong odor of hydrogen sulfide in 1942 but it was much less noticeable in 1951. Despite these conditions, absence of unfavorable competitor species led to a trial with brook trout in 1942 and good fishing has been maintained since then by annual fall stock-

TABLE 1.—*Temperature, carbon dioxide, dissolved oxygen, total alkalinity, and hydrogen-ion concentration—expressed as degrees Fahrenheit and parts per million in Stillwater pond at the deepwater station (27 feet) on July 17, 1951.*

Depth (feet)	Temperature ¹	CO ₂	Alkalinity (CaCO ₃) (M.O.)	Dissolved oxygen	pH
26	65	26.4	12.5	0.8	6.4
20	67	11.6	.....	0.6	6.3
15	72	2.7	12.0	8.4	6.5
10	77	2.9	8.0	8.4	7.0
S	80	1.5	7.0	7.8	7.3

¹Air temperature 78° F. at 3:30 p.m.

ing of fingerlings. It is notable, however, that the life-span of brook trout under these conditions has been short. Recoveries of 3-year-old fish have been less than 1 percent of numbers stocked. During the 7 years of fishing in this water, no 4-year-old fish has been taken either by angling or netting. Fish species present other than trout are black-nosed dace (*Rhinichthys atratulus*) and the mummichog (*Fundulus heteroclitis*.) Neither of these species is abundant but the killifish is more common than the dace, because scarcity of spawning areas limits production of the latter.

To reach this lake fishermen are required to walk about one-half mile. No bank fishing is allowed and each fisherman checks in and out at the boat livery. The catch record, taken as the fishermen check out, is believed to be nearly complete although it is recognized that such infractions as bootlegging fish possessed in excess of the limit may occasionally occur. An attendant is present at all times during fishing hours. The pond supports approximately 10,000 hours of fishing annually.

THE FISH STOCKS TESTED

The stock herein described as "wild" was secured by stripping wild trout taken in the Oswegatchie River main inlet to Cranberry Lake, St. Lawrence County, New York. This lake has long been known for its production of large brook trout (Kendall and Dence, 1929) with 4- and 5-pound trout common in the catch during its earlier history and with one record of a 7-pound fish. Eggs for the stock used in this experiment were taken in 1947 and 1948. Presumably different individual fish were stripped in the 2 years. It may be important that breeders used in 1947 were unselected and included some 9-inch trout whereas in 1948 only eight trout, selected for large size (16-19 inches), were stripped.

Since Cranberry Lake and its tributaries have been receiving substantial plantings of hatchery brook trout for over 50 years it would not be valid to assume that this "wild" stock is a pure derivative from the native Cranberry Lake brook trout. Nevertheless, there is a possibility that characteristic spawning habits have tended to preserve racial purity of the native strain and that the larger trout, particularly, retain hereditary traits of the original stock.

The hatchery stock¹ used is one which has been grown under hatchery conditions without mixture with outside strains since 1902. It has been used extensively for stocking natural waters and is believed to give generally good results. There is at least one well-documented case (Rawson, 1941) in which trout of this stock have been very successful in producing good fishing. This instance is at Maligne Lake, a glacier-fed lake in British Columbia.

¹Eggs were obtained from the Paradise Brook Trout Hatchery, Cresco, Pennsylvania.

TABLE 2.—*Recovery of wild and hatchery trout stocks — expressed for each age group as numbers and percentages of total numbers stocked.*

Year Stocked	Numbers Stocked	AGE GROUP											
		I				II				III			
		Hatchery		Wild		Hatchery		Wild		Hatchery		Wild	
	Hatchery	Wild	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Percent
1948	4,500	1,000	1,791	39.8	166	16.6	228	5.1	155	15.5	15	0.3	1.3
1949	4,500	1,000	1,156	25.7	44	4.4	578	12.8	455	45.5	.....	.....	.....

During early October of both 1948 and 1949, 1,000 fingerlings of the wild stock and 4,500 fingerlings of the hatchery stock were planted in Stillwater Pond. They were mixed at the time of stocking and planted as one lot. In both years the hatchery fingerlings at time of planting averaged approximately three-quarters of an inch longer than the wild fingerlings. The reason for this difference of growth rate in the hatchery is not known. Both wild and hatchery stocks were fed alike and reared under similar conditions. There was a consistent and very noticeable difference in the behavior of the two stocks with respect to wildness, however. The hatchery fingerlings were docile and comparatively undisturbed by approach or motion of nearby objects. The wild fish, on the other hand, were greatly disturbed by approach of a person or by motion over the trough. This timid behavior of the wild strain appears to be an invariable characteristic. Such behavior is recognized to be a handicap to production in hatcheries but its probable value with relation to survival under wild conditions should not be overlooked.

CATCH RECORD

Before they were planted all fish were fin-clipped to allow identification of members of the two groups at the time of recovery. Unfortunately, the poor condition of the fins at the time of clipping in 1948 made it necessary to discard 4 percent of fish recovered from that year class because recognition was uncertain. It is believed that the fish fin-clipped in 1949 were all identifiable on recovery.

The catch record through 1951 is presented in Table 2. It will be seen at once that the heavy recovery (39.8 and 25.7 percent) of hatchery stock occurred in the first year after planting. In the case of the wild fish, however, returns from the 1948 planting were almost as great in the second year as in the first while returns from the 1949 planting were much larger the second year. Data are not available to show why the take of hatchery yearlings was so much higher than that of the wild yearlings. Observations indicate that it was caused by the size of the wild yearlings, however, and was not an indication of better natural survival of the hatchery strain up to and through the first fishing season.

In their second and third seasons of availability to anglers the trout of both strains were of similar size, although they differed in body shape as will be shown later. Since they were nearly alike in size, it seems valid to assume that the catch of both strains was proportionate to the numbers of each present.

If this assumption is made, rates of return (percentages) of each strain relative to numbers remaining after subtraction of the previous catches should provide a measure by which natural survivals of the two strains could be compared from time of planting to the ends of the fishing seasons concerned. Subtraction of previous seasons' catches

is done in order to prevent known losses to anglers from affecting comparisons of natural survival. The number of fish left after this deduction represents the natural losses until the start of the next season plus the number of fish actually present at the beginning of the next season. For example, of the 1948 planting of hatchery trout 228 were taken as 2-year-olds. This number is 8.4 percent of 2,709, the number remaining after the yearling catch (1,791) is subtracted from 4,500. A proportionate catch of wild trout (155) is 18.6 percent of 834, the number remaining after 166 fish were subtracted from 1,000. If angling were equally successful on both groups (as assumed), this would mean that natural survival of the wild trout from planting to the end of second fishing season was better than for the hatchery trout in the ratio of about 18.6 to 8.4. When the disproportionate natural losses of hatchery trout occurred is not certain, but the heavy first-year catch suggests that it occurred sometime after the close of the first fishing season.

Percentages obtained in this way are shown in Table 3. They strongly suggest that the higher rate of catch of wild trout in the second season as referred to the planting rate, is not simply compensation for comparatively low catch rate the first year, but is caused by a better natural survival rate during the period from time of planting to the end of second season.

Comparisons based on percentages of 0.6 (hatchery) and 1.9 (wild) in the one season's record for 3-year-old trout are based upon catches too small to be very significant. The survival ratio favoring the wild strain, however, is greater than it was in the catch of 2-year-olds.

TABLE 3.—*Recovery of trout expressed as percentages after deduction of previous season's catches.*

Year stocked	Age group					
	I		II		III	
	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
1948	39.8	16.6	8.4	18.6	0.6	1.9
1949	25.68	4.4	17.3	47.6	.....	.....

This survival suggests that natural mortalities over the third winter again were less for the wild than for the hatchery strain fish. While the difference in survival rates is clear, there is some possibility that an artificial factor may supply the explanation. Record of the catch, of course, does not include the fish which may have been lost after they were hooked and returned to the water. Losses from this cause are known to occur but the number is believed to be relatively small. The probability that fewer yearlings of the wild stock were taken

because they averaged smaller in size than the hatchery stock yearlings indicates that unrecorded losses of the wild stock from hooking should tend to run higher than for the hatchery stock. Conclusion that the observed difference in survival rates is due to natural rather than to artificial causes seems justified.

The factors causing differential survival rates of the two strains are not known. There is some evidence, however, that better adaptation of the wild stock to high temperatures may be the critical one. At Maligne Lake (Rawson, loc. cit.), trout of the hatchery strain survived over a span of 7 years, according to scale readings. Temperatures in this lake at the surface seldom were higher than 56° F. Cranberry Lake has extensive cold areas near spring holes and stream mouths. Nevertheless, both Cranberry Lake and Stillwater Pond are warm for trout waters (bottom temperature at the near maximum depth of 28 feet in Cranberry Lake, July 12, 1931 was 69° F.).

PHENOTYPIC CHARACTERS OF THE TWO STOCKS

In the fishing seasons of both 1950 and 1951 differences in the appearance of representatives of the hatchery and wild stocks were noted. These differences were observed especially in the 2-year-old trout (those which had been in the pond approximately 18 months) but they may have been more apparent because few representatives of other year groups were observed. Variations in body form of the two groups were noticeable in both 1948 and 1949 year groups, but brighter coloration of fish of the wild stock was noted only in individuals of the 1949 planting. On opening day, 1951, a series of catches of mixed, wild and hatchery 2-year-old fish exhibited these differences so markedly that it seemed possible to separate the two types readily in the field without reference to the clipped fins. The wild fish appeared to be rounder in cross section (less deep) than the hatchery trout, vermiculations seemed to be more definite, and color spots were brighter.

An objective test of the differences in body form was possible from length-weight analysis. Samples of the 2-year-old trout for this analysis were taken on the opening days of the fishing season in both 1950 and 1951. Lengths and weights of all trout were taken as the fishermen brought them in until a large part of each day's catches had been processed. In 1950, trout with fin-clips not definitely referable to one group or the other were discarded and in 1951, three fish for which weights were not recorded were discarded.

Since the 1951 sample (1949 planting) may have included better representatives of the Cranberry Lake, wild stock, and also because the sample was larger and fin-clips were definitely recognizable, this sample was selected for principal use in comparing the length-weight relationships. The sample included 261 trout, of which 109 were wild stock and 152 hatchery stock. In this sample, mean length of the hatchery trout was 10.97 inches and of the wild trout 11.76 inches.

Difference in mean lengths of the two groups is 0.82 inches with a standard error of 0.09 inches, which is highly significant. The mean weight of the hatchery stock was 8.44 ounces and of the wild stock 7.98 ounces. Difference in mean weights is 0.46 with a standard error of 0.18. This difference is also significant.

Since the wild trout were longer and lighter than the hatchery trout, the difference in body form was compared by use of condition factors. The factors were obtained by use of the English system formula as set forth by Klak (1941) as follows:

$$\text{C.F.} = \frac{W \times 100,000}{L^3}$$

where C.F. = coefficient of condition in the English system,

W = weight in pounds,

L = total length in inches,

and 100,000 = factor which places the decimal point usually at the right of two significant figures.

The difference in means of condition factors between samples of the hatchery and wild strains taken in 1950 is less than that found in the 1951 sample (Table 4). Possible reasons for this difference have

TABLE 4. — *Comparison of condition factors (C.F.) of trout of age group II in samples taken in 1950 and 1951.*

Sample	Number in sample		Condition factors (means)		Difference of means	Standard error of difference
	Hatchery	Wild	Hatchery	Wild		
1950	37 ¹	40 ¹	40.59	33.78	6.81	.....
1951	152	109	40.19	30.44	9.75	0.5

¹Thirty additional trout were discarded from the 1950 sample because fin-clips did not allow certain identification of stock.

already been pointed out. Standard error of the difference in means of condition factors for the 1950 sample was not calculated because there may have been errors in recognition of fin-clips.

MANAGEMENT IMPLICATIONS

The greatest number of trout of the hatchery stock was caught in the first year after stocking while the greater percentage of wild stock was taken as 2-year-olds (Table 2). The pattern is similar for fish stocked in both years. It seems that the primary desire of trout fishermen is to catch something, but a close second in order of preference is to have at least the chance to catch a sizeable trout. For Stillwater Pond, therefore, the ideal use of these two strains of trout appears to be the annual planting of both in about equal numbers. The need for

a population which contributes strongly to the catch as yearlings is accentuated by the fact that nearly three-quarters of the 2-year-olds are taken during the first weekend of fishing. Since older fish are extremely scarce, fishing would be poor for the remainder of the season unless yearlings were available to fill the gap.

It is recognized, however, that each situation would require individual consideration. The type of water, intensity of fishing pressure, rate of stocking, and other factors all might influence the choice of strain or combination of strains which should be used. It should be added that at Stillwater Pond, although the numerical yield of hatchery trout from the 1948 stocking was somewhat higher than that of wild trout on a percentage basis, the yield by weight was somewhat higher for the wild trout. Calculated on the basis of samples, the approximate weight of hatchery trout recovered from the 1948 stocking was 17.5 pounds per 100 fingerlings stocked while the return of the wild strain was 19.8 pounds. On the basis of the first two seasons, the total return from the 1949 planting was considerably greater for the wild strain, both numerically (Table 2) and by weight. Calculated on the basis of samples, returns of this year class were 13.2 pounds per 100 hatchery trout stocked and 23.7 pounds per 100 wild trout stocked. Nevertheless, the comparatively heavy return of hatchery-strain trout as yearlings (nearly six hatchery to one wild) strongly favors use of a high proportion of the hatchery-strain trout for plantings in this pond.

It is not the purpose of this paper to point out any generally applicable management formula but to emphasize the potential importance of varieties or physiological races of brook trout with relation to management of brook trout waters. In view of the general recognition of many distinct strains of trout in both natural waters and hatcheries it seems surprising and paradoxical that trout developed for success in hatcheries should be accepted with so little question as satisfactory for stocking wild waters. The fact that development of certain hereditary characteristics is considered important in fish-cultural work should indicate the possible advantages in developing or selecting the right strain for stocking in each water.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the cooperation of personnel of the Taconic State Park Commission, especially of individuals concerned with administration and program activities at Clarence Fahnestock Memorial Park. The continuing interest of Paul T. Winslow, Executive Secretary-Treasurer, and Lester Connelly, Senior Park Superintendent of the Taconic State Park Commission, was particularly helpful. Thanks are due, also, to David C. Haskell, Foreman, State Fish Hatchery, Rome, N. Y., for help with mathematical problems encountered in preparing the manuscript. Other associates in the Division of Fish and Game, N. Y. State Conservation Department, have contributed liberally in various ways during the course of the work.

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MANAGEMENT OF TROUT WATERS IN THE NATIONAL FORESTS OF THE SOUTHERN APPALACHIANS

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ABSTRACT

The management of trout fishing in the National Forests of Virginia, North Carolina, Tennessee, and Georgia is a cooperative effort with Forest Service, the States, and Fish and Wildlife Service participating. The States execute the management programs, provide protection to the resource, operate creel checking stations where these are a part of the program, and sell the special permits. The Forest Service provides the general land management and maintains physical structures on the areas, such as rearing pools, checking stations, and residences for caretakers. Trout for stocking streams are provided by the States and the Fish and Wildlife Service.

Special permits, which are required before fishing, are sold by the States. Half of the revenue received from the sale of special permits is contributed to the Forest Service to be applied toward payment of its share of the costs of the cooperative management program.

During 1950, an estimated 88,058 man-days of trout fishing were enjoyed in the management areas of the four States. The cost of providing a man-day of trout fishing varied on the different areas, from \$1.40 to \$4.41. The revenue received also varied. General administrative costs by the States and Forest Service are not included in the estimate. Although natural reproduction provides a considerable proportion of the trout caught (55 percent in the Tellico, Tennessee, Area), periodic stocking of hatchery-reared trout is considered a necessary and worthwhile feature of the program.

The agencies offering the program feel that it is a good investment in recreational use of wild lands. No claim is made that it is self-supporting, but it approaches that end more nearly than do most fish and game activities where no permit fee is collected and where less intensive management is exercised.

INTRODUCTION

A recognized accomplishment in fish and game management is the program carried on by the Southeastern States in cooperation with the U. S. Forest Service and the Fish and Wildlife Service on Forest Service lands. The primary objective of the program is the fullest possible use of the trout streams in providing a high quality of public fishing. The trout waters in the National Forests of several states have been included in such programs since 1936. The first enabling legislation was passed by the North Carolina General Assembly in 1933, but

¹The senior author was employed by the States of Tennessee (1949-51) and North Carolina (1940-49) in fisheries work, and undertook the preparation of the paper as a representative of the states whose programs are described. The junior author was employed by the U. S. Forest Service as a fisheries technician in the Southeastern Region (1936-45), and has continued to aid the Forest Service in fisheries problems since that time.

Tennessee set up the first cooperative wildlife management areas on the Tellico and Hiwassee Ranger Districts of Cherokee National Forest in 1936. North Carolina and Georgia got their programs underway in 1937, Virginia in 1938.

The plan of management followed varies considerably in the several States, and the question, "Does the program pay?" is frequently asked.

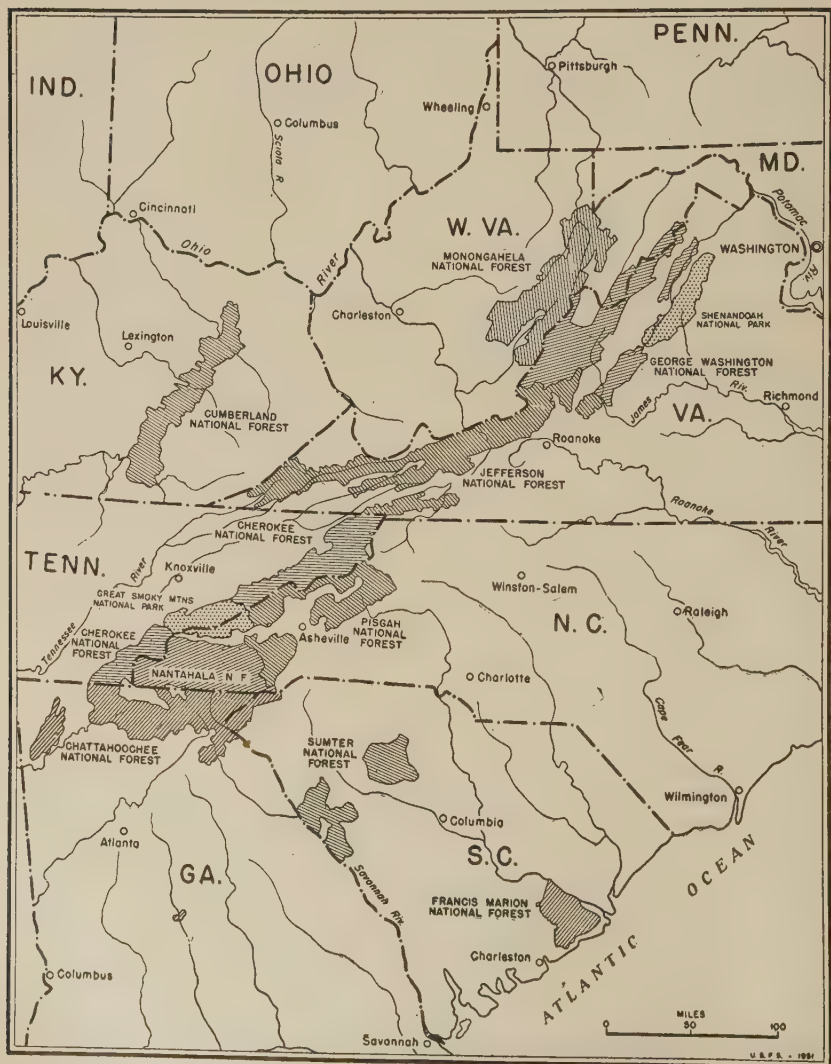


FIGURE 1:—National Forests of the Southern Appalachians.

This paper attempts to explain the plans in operation in the States of Virginia, North Carolina, Tennessee, and Georgia, and show the overall costs. It does not undertake to give angling returns except the summary of data obtained in 1950. Chamberlain and Huber (1947) give a 10-year summary of angling returns for the Pisgah and Sherwood areas.

Cooperative agreements entered into by each of the States and the U. S. Forest Service provide for the interests of both agencies and establish spheres of responsibility. Those Forest Service lands are included in the cooperative areas that can best be protected against trespass, and which are recognized as having the greatest capacity for development and public use. In general, the principal responsibility for protection is borne by the State which employs resident wardens or caretakers, and provides technical supervision. Providing and maintaining physical structures is the job of the Forest Service. Annual meetings are held at which time the work plans and schedules for the ensuing year are discussed and set up for operation. Responsibility for carrying out the management provisions of the program usually rests with the States. One of the accepted policies is that all fishing and hunting on such management areas be under a special permit, which is required in addition to the regular state hunting and fishing license. Revenue derived from the sale of such permits is collected by the States and half contributed to the Forest Service for expenditure on the cooperative management area program in North Carolina, Tennessee, and Georgia. In Virginia, it is set aside in a special State fund, administered by both State and Forest Service. Amounts exceeding the receipts are normally spent by the States in carrying out the management programs on the areas.

The Fish and Wildlife Service cooperates through agreement with the Forest Service whereby it furnishes a portion of the trout required for stocking the streams and performs such technical studies as may be required and requested by the Forest Service.

In matters of jurisdiction, both Federal regulations and State laws and regulations may apply. Most violations are taken before State courts, while some offenders may be tried before a U. S. Commissioner or other Federal court where jurisdiction permits. All prosecutions are reported to the local District Forest Ranger.

PLAN OF MANAGEMENT

Virginia.—Although there is no formal agreement, the State of Virginia cooperates with the Forest Service in a trout stocking program and in developing general management plans. Both the State and the Fish and Wildlife Service provide trout for streams in the Jefferson National Forest and the George Washington National Forest. In Virginia all the National Forest lands are considered to be under a management program. Permission to hunt and fish on these lands is gained by the purchase of a special State stamp for the price of \$1.00 which

TABLE 1.—Summary of creel census data collected in cooperative wildlife areas of Tennessee, North Carolina, Virginia, and Georgia during the 1950 fishing season.

Area	Acreage	Miles of streams	Man-days fishing	Trout ² stocked	Trout caught	Average creel
Tennessee						
Cherokee National Forest						
Tellico Wildlife Area.....	80,000	100	7,429	18,202 S & F	36,500	4.9
Other Tennessee areas (5).....	111,900	84	3,785 E ¹	11,368 S	14,330 E	3.8 E
All Tennessee areas.....	191,900	184	11,214 E	29,570 S & F	50,830 E	4.5 E
North Carolina						
Pisgah National Forest						
Pisgah Preserve & Sherwood area.....	128,283	148	10,972	36,207 F	48,635	4.4
Daniel Boone area.....	46,700	75	2,606	8,750 S	11,084	4.3
Mt. Mitchell area.....	25,200	50	2,813	9,800 Sf	10,652	3.8
All Pisgah Forest areas.....	200,183	273	16,391	8,235 S	70,371	4.3
Nantahala National Forest						
All areas (5).....	84,968	108	4,982	4,091 Sf	28,643	5.7
All North Carolina areas.....	285,152	381	21,373	53,192 S & F	99,014	4.6
Virginia						
George Washington National Forest.....	824,792	112 A 392	33,223 E	13,891 f	N.D.	N.D.
Jefferson National Forest.....	613,435	10 A 152	16,612 E	76,738 S & F	N.D.	N.D.
All Virginia areas.....	1,438,227	122 A 554	49,835 E	108,280 S & F	28,180	5.0 E
Georgia						
Chatahoochee National Forest.....	145,000	193	5,636	35,497 F		
All areas (4)						

¹A—Acreage of ponds also open to public fishing; E—estimated; F—fingerling trout; S—State fish.

N.D.—no data.

²All trout stocked 7 inches or over except as noted.

is good for the season. Forty-five percent of the funds allotted for work on the areas is designated for fishery management activities on the Forests. The remainder is used in wildlife management projects. Creel census data have not been collected in the past, and the man-days of fishing have been estimated only by State and Forest Service personnel.

North Carolina.—The cooperative management area program is developed to a greater degree in North Carolina than in the other states of the Southeast. Eight major areas with a total of 285,144 acres of forest land are included. Special State permits costing \$1.00 per day, in addition to the State fishing license, are required for fishing privileges. The permits to fish are issued at creel checking stations operated on each watershed or principal access point. All fishermen are required to report their catches at the close of each day's fishing. The streams are open on a staggered schedule so as to spread the fishing load as widely as possible, and so that some Forest waters are open nearly every day. The Fish and Wildlife Service operates a trout rearing station on the Davidson River to provide the fish required in the Pisgah Game Preserve and the Sherwood Area. The Service also provides fingerling trout for further rearing in the Arrowwood Glade Station in Wayah Wildlife Area near Franklin. These trout are released in the Nantahala Wildlife Management Areas by the State which provides additional trout for some of the Nantahala areas, and the trout released in the Daniel Boone and Mt. Mitchell Ranger Districts of the Pisgah National Forest. State personnel man the creel stations, do the stocking of fish, and provide protection to the streams and forests.

Tennessee.—The pattern followed in Tennessee is very similar to that in North Carolina. Only one area, the Tellico, has been under intensive management. Five other areas, all located in eastern Tennessee, have been open to public fishing but without the permit system and the full management program provided on the Tellico Area. The permit system in force on the Tellico Area is being extended to the other areas in Tennessee in 1951. As complete a creel census as possible is taken on the Tellico (see Table 2). The Fish and Wildlife Service provides most of the trout required. These are received as large fingerlings and held for further rearing, in pools provided and maintained by the Forest Service but operated by the State. State personnel distribute the trout, operate the creel stations, and do law enforcement work.

Georgia.—There are four wildlife management areas in the Chattahoochee National Forest containing a total of 145,000 acres. These are managed similarly to the North Carolina areas, except that complete creel census is not obtained. The Fish and Wildlife Service operates the Rock Creek rearing station, the entire output of trout going on the management areas. Additional trout are furnished by the Fish and Wildlife Service for the Lake Burton Area from the Walhalla, South Carolina, hatchery. From time to time the State has furnished some

trout for the wildlife management areas but usually the State fish are planted in National Forest waters outside the management areas. Creel returns are estimated from a spot check of creels.

In all cooperative areas periodic stocking of catchable-sized trout is carried on. Since practically all of the streams support natural reproduction of trout, planting of fingerling trout was discontinued in most of the areas several years ago. The system of opening a stream to fishing 2 to 4 days and then closing it for a like period is regarded with favor in North Carolina, Georgia, and Tennessee. Trout anglers believe this system is a big factor in maintaining a satisfactory catch of trout. In addition, the plan enables a smaller personnel to man creel checking stations, sell permits, and carry on law enforcement, than where the streams are open every day. The success of the program has been due in large measure to the fine cooperation shown by the agencies involved.

The results of the program have not been accurately evaluated from an economic standpoint, but there has been a marked change in the economic status of some communities. Availability of fishing equipment and overnight accommodations and the number of summer guests has greatly increased in the vicinity of the fishing areas in Tennessee. Similar but less marked results have been experienced in North Carolina.

The trout fishery is managed to maintain and distribute the angling throughout the summer season rather than to attract large crowds and give a brief period of satisfactory angling at the beginning of the season. In Virginia, although some sustaining plants of trout are made after the trout season opens and fishing is permitted continuously throughout the season, most of the angling is done during the first 2 or 3 weeks of the open season. Because of the alternating valley and ridge topography which is accompanied by scattered trout waters and numerous private holdings, the National Forests of Virginia do not lend themselves to the more intensively controlled type of management that can be done where large areas of trout waters occur in a consolidated acreage.

ANALYSIS OF TELlico CREEL CENSUS

Creel data for the 1950 season, Tellico Wildlife Management Area, are summarized in Table 2. Hatchery fish provided 45 percent of the trout taken while nature produced 55 percent of the catch. It is possible that this latter figure includes some trout previously stocked and carried over winter in the streams since stocked fish were not marked in seasons prior to 1950. Inasmuch as the creel returns are incomplete from some of the more inaccessible streams, where little stocking was done, the catch of naturally produced fish is probably somewhat greater than 55 percent of the total. In spite of the high contribution of naturally reared fish, the catch of hatchery fish made the difference between good and poor fishing for a lot of anglers, and the knowledge that the streams had been recently stocked increased the fisherman's confidence. All trout

stocked in 1950 were marked by clipping the right ventral fin, and creel checking stations were manned every day the streams were open to fishing. Recovery of stocked trout was excellent, reaching 90 percent.

COSTS OF THE PROGRAM

No claim is made in this paper that trout fishing can be made a paying venture, under public management of the type described here. The cooperative management areas afford the best in natural conditions, where some natural trout reproduction occurs, where silting and erosion are at a minimum, and where laws and regulations can be most readily enforced. It can be determined from cost figures provided by the several agencies (Table 3) that the average investment in each trout taken varied from 47 cents in Tennessee to 85 cents in Georgia, with Virginia not having data sufficient for an estimate (Table 4). The cost of providing a man-day of trout fishing which probably is a more significant figure, is a highly variable sum (Table 4). It ranged from \$1.40 in Virginia to \$4.41 in Georgia. Virginia's low figure can be explained

TABLE 2.—Summary of creel census data of 58.7 percent of all anglers, 1950 season, Tellico Cooperative Wildlife Management Area, Tennessee.

Item	Total from anglers reporting	Estimated totals
Fisherman days.....	4,362	7,429 (permits sold)
Total catch.....	21,431 trout	36,500 trout
Average creel (all anglers).....	4.9 trout	4.9 trout
Total weight of trout.....	4,592 lbs. (plus X)	7,821 lbs. (plus X) ¹
Stream-reared trout taken.....	11,784	20,075 (plus Y) ²
Stocked trout recovered.....	9,647	16,425 (minus Y)
Percentage of catch, stream-reared trout.....	55	55
Percentage of catch, stocked trout.....	45	45 (Z) ³
Percentage of anglers who were successful.....	72	72
Average creel of successful anglers.....	6.7 trout	6.7 trout
Average weight of creel of successful anglers.....	1.44 lbs.	1.44 lbs.
Percentage of marked trout recovered.....	53	90 (minus Z)
Catch by species: Rainbow.....	19,881 (93 percent)	33,945
Brook.....	1,345 (6 percent)	2,190
Brown.....	205 (1 percent)	365

¹X—Many trout were partially dressed when weighed and not so recorded on creel census card.

²Y—Streams less thoroughly covered by census were in back-country areas and a larger percentage of stream reared trout was taken.

³Z—The stocked trout were placed largely in the most accessible and heavily fished streams, suggesting that less than the estimated percent were recovered.

A total of 18,202 trout from 7 to 12 inches in total length were stocked in 1950, April to September.

in part by possible gaps in the data since the man-days of fishing are estimates only and the number of trout stocked in the Forests by the State is not clearly indicated in available reports. On the other hand, Georgia reported a very low number of man-days of fishing, in contrast to the number of fish stocked and expenses incurred in connection with management. The Georgia streams may be underfished while the pressure on the Virginia streams is very heavy.

TABLE 3.—Total costs of management, cooperative wildlife areas, 1950 season.

Area	Protection	State costs			U.S. Government costs		All costs
		Trout stocked	Creel census, surveys, etc.	State costs Total	Forest Service	Fish and Wildlife Service	
Tennessee							
Tellico Area.....	\$ 2,050	\$ 5,948	\$ 910	\$ 8,908	\$ 3,536	\$ 1,967 b	\$14,411
Other Tennessee areas (5).....	6,175	3,790	270	10,235	100	85 c	10,420
All Tennessee areas.....	8,225	9,738	1,180	19,143	3,636	2,052	24,831
North Carolina							
Pisgah and Sherwood area.....	9,998	.....	836	10,834	.....	9,440	21,352
Daniel Boone area.....	3,334	3,940	504	7,778	.....	.....	8,086
Mt. Mitchell area.....	3,334	3,880	492	7,706	.....	.....	7,721
All Pisgah Forest areas.....	16,666	7,820	1,832	26,318	9,530 f	9,440	45,288
Nantahala National Forest							
All areas (5).....	8,334	5,886	1,202	15,422	1,097	1,425 d	17,944
All North Carolina areas.....	25,000	13,706	3,034	41,740	10,627	10,865	62,962
Virginia							
George Washington National Forest.....	3,000	6,000	5,137 a	14,137	5,137 a	15,742	35,016
Jefferson National Forest.....	3,200	19,937	2,568 a	25,705	2,568 a	6,855	35,128
All Virginia areas.....	6,200	25,937	7,705 a	39,842	7,705 a	22,597	70,144
Georgia							
Chattahoochee National Forest							
All areas (4).....	11,375	.....	.....	11,375	5,900	7,568	24,843

a—The receipts from sale of permits are handled as one fund, and jointly administered; b—15,000, 5 to 6 inch trout; c—15,000, 2-inch trout; d—22,000, 5 to 6 inch trout; f—for 1950-51 fiscal year.

The revenue received for each fisherman day in North Carolina, Tennessee, and Georgia is \$1.00 plus the proportionate value of the State fishing license. This will vary from a few cents for residents who fish a great deal to as much as \$1.00 per day in North Carolina for non-residents who purchase the 1-day permit rather than the seasonal license. In Virginia, the \$1.00 permit is good for the season, the resident license costs \$3.00, but non-residents of Virginia must purchase a license costing \$10.00 before fishing 1 or more days.

The point is worthy of consideration that the management areas come nearer to paying their own way, insofar as trout fishing is concerned, than do outside waters. The heavier use by anglers, accompanied by the payment of the special permit fee plus the State license, brings in

TABLE 4.—*Summary of income, expenditures, cost per fish, and cost per fishing day, cooperative wildlife management areas, 1950 season.*

Area	Receipts from permits	Total expenditures	Man-days fishing	Cost of each man-day of fishing	Value of each trout caught
All Tennessee areas.....	\$ 7,429	\$24,831	11,214 E ¹	\$2.21	\$0.47
All North Carolina areas..	21,373	62,962	21,373	2.94	0.63
All Virginia areas.....	22,426	70,144	49,835 E	1.40	I ²
All Georgia areas.....	5,636	24,843	5,636	4.41	0.85

¹E—Estimated.

²I—Insufficient data on catch to determine cost.

revenue which would not otherwise be received. Few if any fish management programs are entirely self-supporting. The cooperatively managed areas, where multiple land use is the governing principle, come as close to the ideal program as possible.

CONCLUSION

The importance placed on the program as summed up in the report provided by Harry Cornell, Chief, Fish Division, North Carolina Wildlife Resources Commission, is typical of comments received, and the conclusion of the authors:

"While it is apparent that the income from the sale of permits does not equal the cost of stocking and management, this is still believed to be an economically sound program.

"There is no direct return from the stocking of trout in the other public fishing waters of the State. The income from the sale of permits is believed to equal the excess in management costs on the cooperative management areas over the management costs of other public waters of the State. In addition, the excellence of fishing in these management areas encourages the sale of more fishing licenses, and also provides the major attraction in bringing considerable income to the State in the form of tourist business. It is believed that the trout fishing program on the cooperative management areas represents no financial loss to the Wildlife Resources Commission and is of considerable benefit to the State of North Carolina."

ACKNOWLEDGMENTS

The writers are greatly indebted to the State directors and fisheries biologists of the States of Virginia, North Carolina, Tennessee, and Georgia, for their willingness to make available the data necessary for a report of this type. The Forest Service gave data from its files and all Forest Service Supervisors contributed fiscal and management data for their respective forests. Records of trout provided and their costs were furnished by the Fish and Wildlife Service.

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A MEASURE OF THE EFFICIENCY OF ALTERNATING AND DIRECT CURRENT FISH SHOCKERS¹

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ABSTRACT

Two shockers, one powered with a 500-watt, 110-volt, 60-cycle alternating current generator, the other with a 2,500-watt, 230-volt, direct current unit, were compared in two blocked-off sections of Spring Brook, Kalamazoo County, Michigan. An indication of the efficiency of the D. C. unit in recovering marked fish from extremely turbid water was obtained in an unblocked section of Wilder Creek, Calhoun County, Michigan, where the use of the A. C. machine was impracticable. In one Spring Brook section, the fish were shocked, marked, and recovered first with the A. C. unit and then with the D. C. The procedure on the other section was similar except that D. C. was used first.

In the swifter section, recoveries of individual species varied from 0.0 to 100.0 percent with both shockers. Of the total marked fish present, 44.8 percent were recovered with D. C., 28.8 percent with A. C. In the other section, the recoveries by species varied from 9.1 to 66.7 percent. Here, 41.2 percent of all marked fish present were taken with D. C., 35.1 percent with A. C. Combined results on both sections indicated a rate of recovery of 42.9 percent with D. C. and 33.3 percent with A. C. Although a single recovery of 75.0 percent was noted for one species on Wilder Creek, the total recovery of all species was only 16.4 percent. Of the two shockers described, the D. C. unit seemed to give much better results, particularly in swift and turbid waters.

INTRODUCTION

Both alternating current (A.C.) and direct current (D.C.) electricity have been widely used in Germany since 1926 in the collection of fish for commercial and scientific purposes (Schiemenz and Humburg, 1939). Haskell (1940) reported on the first recorded use of electricity in North America to collect fish for population studies. Several modifications of Haskell's apparatus were described in the next decade (Prevost, 1945; Shetter, 1947; Funk, 1949; Joeris, 1949; and Morris, 1950). These modifications were similar in that they all employed A. C., but differed principally in the type of electrode used to convey the current to the water.

Since Rayner (1949) reported on the use of D. C. in Oregon, the D. C. fish shocker has assumed increased importance in North American stream population studies. However, all workers who have used

¹Contribution from the Michigan Institute for Fisheries Research.

this type are not in agreement on the results obtained. The difference in results appears to be due to differences in water conditions and in the design of the equipment.

Rayner (1949) claimed a superior performance by D. C. over A. C., especially in turbid and swift water. His apparatus consisted of a 230-volt, 2,500-watt D. C. generator, a 16-inch by 36-inch piece of copper hardware cloth used as the negative electrode, and two dip nets, each threaded with copper wire, used as the positive electrodes.

Smith and Elson (1950) found an advantage in the use of the Wolf D. C. shocker in taking smaller fish and in removing fish from hiding places. The Wolf unit can supply a maximum current of about 5 amperes at 250 volts, or a power output of 1,250 watts. The electrode arrangement differed from that of Rayner in that the positive electrodes were metal grids on insulated handles. Scap nets were used to recover the stunned fish from the water.

Webster (1950) reported definitely unsatisfactory results with D. C. in attempting to compare the efficiency of the two types of current in Fall Creek, New York, but as he pointed out (personal communication) the experiment was primarily a demonstration and not an exhaustive test. The current supplied by the 230-volt, 2,500-watt D. C. unit was conveyed to the water by electrodes of two types. One consisted of two hand-held, 10-inch sheet aluminum paddles, the other a grounded system in which the negative pole made contact with the ground, either by iron stakes or by bare, weighted wires dragging on the bottom. Had a different type of electrode been used, results might have been improved. When two aluminum plates are used as electrodes, a high resistance is built up in one which greatly reduces the current flow and hence the effective shocking power. Schiemenz and Humburg in 1939 pointed out that poorer results are usually obtained when one electrode is grounded and explained that the field is made weaker by being spread out over a larger area.

The relative efficiency of the two units currently used by the Institute for Fisheries Research was measured during the summer of 1950 in a limited number of trials. The tests were made in Spring Brook, Kalamazoo County, and in Wilder Creek, Calhoun County, Michigan.

EQUIPMENT AND METHODS

The alternating current power plant tested consisted of a 110-volt, 500-watt, 60-cycle, single phase generator and attached, air-cooled, gasoline-driven motor. The complete unit weighed 63 pounds. Each of the two hand-held electrodes was made by winding 60 feet of 12-gauge copper wire around a 10-inch by 18-inch frame of $\frac{1}{4}$ -inch bronze tubing. The frame was bolted to a wooden rake handle for support.

The direct current power was furnished by a 230-volt, 2,500-watt, gasoline-driven generator, the total weight of which was 135 pounds.

A sheet of copper approximately 14 inches by 8 feet, mounted on the bottom of the boat used to float the shocker, served as the negative electrode. The two positive, hand-held electrodes consisted of wooden handles on each of which was bolted a 9-inch by 12-inch loop of $\frac{1}{4}$ -inch copper tubing. To this framework, 12-gauge copper wire was soldered in such a way that a grid of $1\frac{1}{2}$ -inch squares was formed. The complete electrode resembled a long-handled, coarse-meshed tennis racket.

Blocking of the test sections was accomplished by means of seines supported by chicken wire and iron fence posts driven into the stream bottom. Rocks and gravel were piled on the bottom of the seine to prevent washing out. In operation, the generator was placed in a shallow-draught plywood boat and towed behind the two operators. The stunned fish were collected with scap nets and placed in a tub of water in the boat. At frequent intervals, the captured fish were marked by clipping off a part of a fin and were returned to the water. Two shocking runs were made with each unit in each section with the exception of the one on Wilder Creek. Here the water was too roily for satisfactory results with A. C. The interval between runs on each section was kept between 6 and 24 hours. These limits were set to reduce possible errors resulting from: (1) attempting to recapture fish which had not completely recovered from earlier electrical shock and (2) the removal of fish from the sections by fishermen. It is believed that no error resulted from these causes.

In the lower, swifter section on Spring Brook, the fish were shocked first with D. C., marked, and returned to the water. They were recovered later on a second run with the same unit. The same procedure was repeated with the A. C. unit after the fish had been given time to recover. In the upper section, the procedure was similar except that the A. C. shocker was employed first and was followed by the D. C. trials. Because the conditions on Wilder Creek described below were not entirely satisfactory, only the results of the direct current trials were recorded.

Both Spring Brook and Wilder Creek are two of the better southern Michigan trout streams. The physical and chemical characteristics of both streams are such that electrical fish shockers should provide satisfactory results. During the time of the experiment, the total hardness of each was within 235 to 270 p.p.m. calcium carbonate while the resistivity remained between 2,350 and 2,700 ohms per cubic centimeter. Throughout the entire spring and summer of 1950, dredging operations on Wilder Creek kept the water so roily that unsatisfactory results were obtained with the A. C. shocker.

The upper section chosen on Spring Brook was 500 feet long and it averaged 12.3 feet in width and 2 feet in depth. There were no pools over 3 feet deep. The water was very clear and slow-moving. The lower 300-foot section averaged 12.1 feet in width and 1.5 feet in depth. There was one pool 3 feet deep. The water was much swifter in the lower section and this condition made recovery of fish more difficult.

TABLE 1.—The total number and percentage of fish recovered with alternating and direct current fish shockers.

	Direct Current					Alternating Current				
	Species	Number marked fish present	Number recovered		Percentage recovery	Number marked fish present	Number recovered		Percentage recovery	
			Marked	Un- marked			Marked	Un- marked		
Spring Brook Lower section	Brown trout.....	49	26	11	53.1	35	10	4	28.6	
	Rainbow trout.....	17	11	6	64.7	5	4	2	80.0	
	Brook trout.....	2	2	0	100.0	1	1	0	100.0	
	Common sucker.....	19	0	13	0.0	0	0	2	0.0	
	Sculpin.....					11	0	1	0.0	
	Total.....	87	39	30	44.8	52	15	9	28.8	
Spring Brook Upper section	Brown trout.....	43	21	31	48.8	57	20	16	35.1	
	Rainbow trout.....	18	11	6	61.1	21	6	5	28.6	
	Common sucker.....	11	6	4	54.5	25	13	6	52.0	
	Blacknose dace.....	15	5	17	33.3	9	6	26	66.7	
	Sculpin.....	22	2	37	9.1	22	2	17	9.1	
	Total.....	109	45	95	41.2	134	47	70	35.1	
Wilder Creek ¹	Brown trout.....	37	18	14	48.7					
	Rainbow trout.....	16	12	7	75.0					
	Brook trout.....	3	1	1	33.3					
	Mudminnow.....	128	6	112	4.7					
	Common sucker.....	1	0	2	0.0					
	Creek chub.....	1	0	0	0.0					
	Sculpin.....	39	0	36	0.0					
	Total.....	225	37	172	16.4					

¹Wilder Creek was so rocky that the few fish taken with A. C. in the first shocking did not warrant a second trip.

The dredging on Wilder Creek made it impossible to maintain a barrier seine without constant cleaning. For this reason, a 1000-foot open section was selected which averaged 14.2 feet in width and 2 feet in depth. It was felt that the error caused by driving fish out of an unblocked area would be reduced by increasing the length, for it had been noticed that fish would be driven only short distances ahead of the electrodes before they would return and enter the electrical field. Although the conditions were not strictly comparable, the error introduced was probably insignificant.

NUMBERS OF FISH RECOVERED

The results of the comparisons are shown in Table 1. The recovery by individual species in the lower section of Spring Brook varied from 0.0 to 100.0 percent of the marked fish present with both the A. C. and D. C. units. This great variation was no doubt due largely to the variation in size and abundance of the species represented. The larger trout were more easily seen and were shocked at greater distances from the electrodes than were the very small sculpins. In swift water the operators had more time to net large fish shocked with A. C. before these fish were carried beyond reach and out of the field by the water current. The attracting power of D. C. was much more noticeable on larger fish with the result that some of the large trout appeared to "hang" from the positive electrodes for as long as 30 seconds. The very small specimens of all species appeared to be attracted to the electrodes for a much shorter period of time.

Of the 87 marked fish present in the lower section, 39 fish or 44.8 percent were recovered with the D. C. unit. A recovery of 15 fish or 28.8 percent of the 52 marked fish was accomplished with the A. C. shocker. Under the above conditions, the rate of recovery with the A. C. shocker was 64.3 percent of that with D. C. The total number of fish taken in the two runs with the A. C. unit was only 52.1 percent of the corresponding number taken by D. C.

In the upper section on Spring Brook where the water was not so swift, the results of the two units are more nearly alike. The percentage recoveries by species varied from 9.1 to 66.7 percent. Of all marked fish present (109 fish) 41.2 percent (45 fish) were retaken with the D. C. unit. With the other shocker, 35.1 percent (47 fish) of the total (134 fish) were recovered. These figures indicate that in slow-moving, clear water, the rate of recovery with A. C. was 85.2 percent of that with D. C. Under the above conditions, however, the total number of fish taken in the two runs with each type of shocker was the same (204 fish). The combined results on both sections indicate a rate of recovery of 42.9 percent with direct current and 33.3 percent with alternating current.

In spite of the unfavorable conditions which made the use of the A. C. shocker impracticable on Wilder Creek, a 75.0 percent recovery of marked rainbow trout was obtained with the D. C. unit. The recovery of all species combined, however, was only 16.4 percent. In other words, only 37 of the 225 fish known to be present were retaken.

Although the trials were limited, they do indicate that, of the two shockers described, the D. C. machine was superior in all situations. The advantage was more pronounced in the swift and roily stream where attraction of the fish to the positive electrodes made it possible to net fish which probably would have been lost with the A. C. shocker. The advantage was less noticeable in slow-moving, clear water, and alternating current would probably suffice under such conditions.

ACKNOWLEDGMENT

Financial assistance was given by the Sport Fishing Institute, Washington, D. C.

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RESULTS OF THE FIRST YEAR'S TAGGING OF MULLET, *MUGIL CEPHALUS* L., ON THE WEST COAST OF FLORIDA¹

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ABSTRACT

This paper reports results of the first year's tagging experiment on black or striped mullet, *Mugil cephalus*, carried on by the Marine Laboratory of the University of Miami on behalf of the Florida State Board of Conservation. Mullet support the most important commercial fishery in Florida with average annual landings from 1939 to 1949 of 39,000,000 pounds. Part of this catch is silver mullet, *M. curema*, but most of it is black mullet, *M. cephalus*. Mullet were tagged with Petersen tags at 12 locations on the Florida west coast, from Naples to Pensacola. A total of 1,050 tagged fish were released the first year. The total recovery of tags was 26.5 percent, and the maximum recovery for one location was 50 percent. A higher return was made by the fishery from Apalachicola west to Pensacola (37.0 percent) than from St. Marks south to Naples (20.6 percent). This result suggests that there is a more intense fishery in the northwestern part of the state. Most tagged mullet were recaptured within comparatively short distances from the place of tagging, 89.8 percent having travelled not more than 20 miles. The longest migration was 150 miles. A slightly increased tendency to migrate greater distances was shown by fish free the longest period of time, and by fish at large over the winter spawning period. Over 85 percent of fish free during spawning were recaptured within 20 miles of the tagging locality. Doubt is cast by these results on the popular view that Florida mullet undergo extensive migrations. The high rate of return of tags suggests an intense fishery.

INTRODUCTION

The striped or black mullet (*Mugil cephalus*) supports the most important commercial fin fishery in Florida. Figures compiled by the Florida State Board of Conservation show that an average of 39,000,000 pounds of mullet have been landed each year from 1939 to 1949. In this period the mullet constituted an average of 45.9 percent of the food fish landed in the state. While the accuracy of these landing figures is doubtful, it is likely that they are too low rather than too high. In any case the importance of the mullet compared with other food fish caught commercially in Florida is probably approximated by the statistics. An error is introduced by the failure of these statistics to differentiate between two species of mullet caught in the commercial fishery. Most of the landings are of the black mullet, *Mugil cephalus*, but important quantities of silver mullet, *M. curema*, are also caught. It is shown by the new monthly statistical system introduced

¹Contribution No. 71 from the Marine Laboratory, University of Miami.

in September, 1950 that landings from that month to April, 1951 consisted of 13,599,000 pounds of black mullet and 2,273,000 pounds of silver mullet (Florida Landings, September-April).

Mullet are sold mainly in the fresh fish trade, and are marketed in the round. Some are smoked. The chief market is in the southern states. The fishing takes place over the whole coast of Florida, but

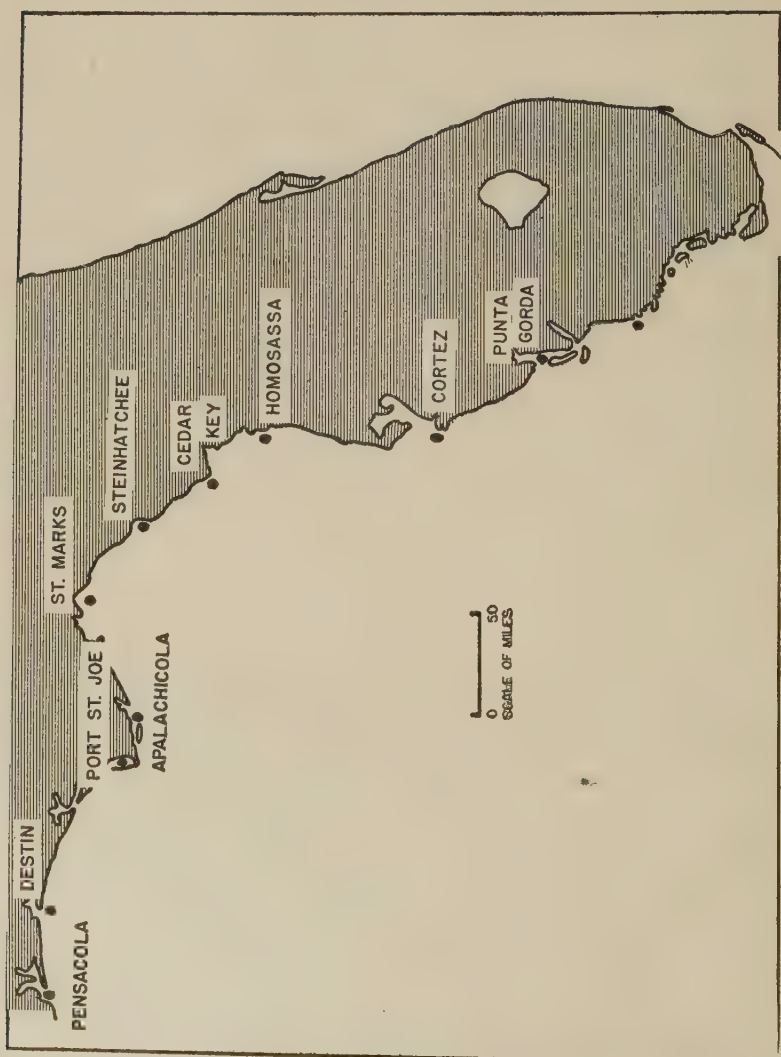


FIGURE 1.—West coast of Florida with stations of tagging and recovery of mullet.

the west coast produces more than the east. The principal fishing gears are gill nets, trammel nets, beach seines, and stop nets (Idyll, 1949). A crew of two men is normally used in these operations, although when beach seines and stop nets are employed, as many as five men may be employed. Catches are largest in the winter when the mullet school for spawning. A closed season is in effect from December 10 to January 20. Landings are lowest in the summer months from June through August.

There is considerable doubt as to whether the present regulations governing the mullet fishery are in all cases correctly designed. In a state as large as Florida ecological conditions vary widely in different parts of the coastal waters. This variation may significantly affect different mullet populations, with reference to size at maturity and spawning time, and may result in the development of several races which require different regulations. It has been frequently suggested by those in the industry that a more intense fishery takes place in the western part of the state, and results in the capture of smaller-sized fish in that area. The tagging experiments described below were designed to investigate these problems and to show the variation in fishing intensity from one part of the area to another. The experiment has been carried on by the Marine Laboratory of the University of Miami for the Florida State Board of Conservation.

TAGGING LOCATIONS AND METHODS

From July 15, 1949 to May 16, 1950, 1,050 mullet were tagged at 12 locations, from below Naples to Pensacola on the west coast of Florida (Figure 1, Table 1). Petersen-type tags consisting of two red plastic discs 13 millimeters in diameter secured to the fish by a nickel pin were used in this experiment. One disc bore a serial number and the other the inscription "Marine Lab, Univ. of Miami. Return whole fish. REWARD." The mullet were caught with beach seines, gill nets, trammel nets, and cast nets. Where it was possible the fish were taken directly from the net, tagged and released. In the cases where they could not be tagged as fast as they were caught, they were kept in a holding box 40 by 26 by 26 inches covered with cotton netting and provided with a lid. All fish were carefully inspected for injuries and only apparently unharmed, vigorous specimens were tagged. In one case at Port Saint Joe some of the fish were not in good condition when they were released. This fact was noted during the operation, and only 41 tags were attached. It is probable that some fish died shortly after release. Tagging was done in a wooden box with a shallow trough consisting of canvas sides and a wooden strip running the length of the box into which a meter stick was set flush with one end. Before tagging commenced the numbered discs were placed on pins in numerical order on the side of the tagging box. The unnumbered discs were placed in the right hand side of the box. When a fish was

placed in the tagging box, three or four scales were loosened from the area directly under the dorsal fin and above the lateral line and were placed in a numbered coin envelope, or on the page of a record book opposite the appropriate tag number. The tag pin was thrust through the muscle of the back where the scales had been removed, the baffle was applied, the point of the pin was cut off, and the free end of the

TABLE 1.—*The number of mullet marked on the west coast of Florida in 1949 and 1950 returned in 1949 and 1950—returns expressed as total number and percentage of total number marked.*

Place tagged	Date tagged	Number tagged	Number returned	Percentage returned
Cedar Key.....	7-16-49	80	16	20.0
Steinhatchee.....	7-18-49	84	27	32.1
	7-19-49			
St. Marks.....	7-20-49	87	13	14.9
	7-21-49			
Apalachicola.....	7-22-49	100	50	50.0
Pt. St. Joe.....	7-23-49	41	7	17.1
Destin.....	7-24-49	64	26	40.6
Punta Gorda.....	8-22-49	100	31	31.0
	8-23-49			
Naples.....	8-25-49	41	0	0
Cortez.....	8-29-49	51	12	23.5
Steinhatchee.....	10-25-49	82	16	19.5
Homosassa.....	11- 9-49	44	8	18.2
Apalachicola.....	12- 7-49	99	34	34.3
Pensacola.....	2-20-50	29	9	31.0
Niceville.....	2-21-50	43	13	30.2
	4-15-50			
	4-16-50			
St. Marks.....	4- 7-50	85	13	15.3
Cedar Key.....	5-16-50	20	3	15.0
Total.....		1,050	278	26.5
St. Marks to Naples.....		674	139	20.6
Apalachicola to Pensacola.....		376	139	37.0

pin twisted in a knot. The length of the fish from the end of the snout to the fork of the tail was recorded in millimeters and the fish released.

All tags were recovered from the commercial fishery. Large placards were sent to all fish dealers in the state to advertise the program. A reward of 50 cents each was offered for the return of the whole tagged fish (or an outline traced on paper, with a few scales from the fish)

accompanied by data on time and place of capture. Where the fish was not returned, or incomplete data were supplied, a 25-cent reward was offered. Fishermen were requested to turn fish over to the dealers for refrigeration and the dealers were asked to inform the Laboratory of the capture of a tagged fish by means of post cards supplied for the purpose. Some fish were sent directly to the Laboratory.

RATE OF TAG RETURN

Of the 1,050 tagged fish released 278, or 26.5 percent, were returned in 1949 and 1950. The proportion of tagged fish recaptured from the groups marked at different locations varied from zero at Naples to 50.0 percent at Apalachicola (Table 1). The rate of tag returns was 37.0 percent in the area from Apalachicola to Pensacola and 20.6 percent from St. Marks to Naples. This difference suggests a higher

TABLE 2.—Number and percentage of mullet tagged at various locations and recovered at different distances from point of release.

Place tagged	Date tagged	Length of migration in miles								Total
		0-20		21-50		51-100		Over 100		
		Number	Per-cent	Number	Per-cent	Number	Per-cent	Number	Per-cent	
Cedar Key.....	7-16-49	16	100	.....	.....	.....	.....	.....	.....	16
Cedar Key.....	5-16-50	2	66.7	.....	.....	.....	.....	1	33.3	3
Steinhatchee.....	7-18-49 7-19-49	25	92.6	1	3.7	1	3.7	.....	.....	27
Steinhatchee.....	10-25-49	11	73.3	2	13.3	2	13.3	.....	.....	15
St. Marks.....	7-20-49 7-21-50	12	92.3	.....	.....	1	7.7	.....	.....	13
St. Marks.....	4- 7-50	10	76.9	1	7.7	2	15.4	.....	.....	13
Apalachicola.....	7-22-49	42	89.4	4	8.5	.....	.....	1	2.1	47
Apalachicola.....	12- 7-49	29	87.4	4	12.1	.....	.....	.....	.....	33
Pt. St. Joe.....	7-23-49	6	85.7	1	14.3	.....	.....	.....	.....	7
Destin.....	7-24-49	25	96.1	1	3.9	.....	.....	.....	.....	26
Punta Gorda.....	8-22-49 8-23-49	30	96.8	1	3.2	.....	.....	.....	.....	31
Naples.....	8-25-49	0	.....	.....	.....	.....	.....	.....	.....	0
Cortez.....	8-29-49	10	83.3	2	16.7	.....	.....	.....	.....	12
Homosassa.....	11-9-49	5	62.5	3	37.5	.....	.....	.....	.....	8
Pensacola.....	2-20-50 2-21-50	9	100	.....	.....	.....	.....	.....	.....	9
Niceville.....	4-15-50	13	100	.....	.....	.....	.....	.....	.....	13
Total.....	.....	245	89.8	20	7.3	6	2.2	2	0.7	273

rate of exploitation in the western part of the fishery, which may be related to the smaller average size of the fish reported from that area. Errors may have been introduced by such factors as differential mortality of tagged fish, loss of tags, failure to report tags caught, and differential vulnerability of tagged fish to capture. The effects of these errors have not been evaluated. Therefore, while the percentage returns of tags are being considered as only approximate indications they suggest that the rates of exploitation in the commercial fishery are high.

MIGRATION OF MARKED FISH

It is apparent from the returns that most of the recoveries were made in the same general area where the fish were tagged (Table 2). Of these 273 recoveries, 245 (89.8 percent) were made within 20 miles of the place of tagging. Twenty (7.3 percent) were recaptured from 21 to 50 miles from the tagging location, 6 (2.2 percent) had travelled from 51 to 100 miles, and 2 (0.7 percent) had gone over 100 miles. The latter two tagged fish had travelled 110 miles (Apalachicola to Steinhatchee), and 150 miles (Cedar Key to Apalachicola).

TABLE 3.—*Number and percentage of mullet recaptured at different distances from point of release more than 90 days after marking.*

Place tagged	Length of migration in miles						Total
	0-20		21-50		51-100		
	Number	Percent	Number	Percent	Number	Percent	
Cedar Key.....	7	100					7
Cedar Key.....	0						0
Steinhatchee.....	5	71.4	1	14.3	1	14.3	7
Steinhatchee.....	3	75.0	1	25.0			4
St. Marks.....	0						0
St. Marks.....	6	75.0	1	12.5	1	12.5	8
Apalachicola.....	4	100					4
Apalachicola.....	13	92.8	1	7.2			14
Pt. St. Joe.....	3	100					3
Destin.....	0						0
Punta Gorda.....	4	80.0	1	20.0			5
Cortez.....	0						0
Homosassa.....	2	50.0	2	50.0			4
Pensacola.....	8	100					8
Niceville.....	5	100					5
Total.....	60	87.0	7	10.1	2	2.9	69

TABLE 4.—Distances travelled by tagged mullet free over the spawning period and by mullet not free over the spawning period—enumerated on the basis of length of time before recovery.

Days free	Distance migrated in miles													
	Free during spawning period						Not free during spawning period							
	Less than 20		21-50		51-100		Less than 20		21-50		51-100		Over 100	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1-90.....	23	85.2	2	7.4	2	7.4	141	93.4	8	5.3	1	0.6	1	0.6
91 and over...	41	85.4	6	12.5	1	2.1	21	91.3	1	4.3	1	4.3	.....	.....

Many tagged fish were recaptured soon after release, so that failure to migrate long distances might have been merely the result of lack of sufficient time for much movement. That this was not the controlling factor is shown by the fact that mullet free from 90 to 362 days were generally recaptured in the same area where they were tagged, 87.0 percent having travelled no more than 20 miles (Table 3). Length of time since marking does have an effect on the distance migrated, but the general conclusion that the normal behavior of the fish is to remain in one area for a considerable time is not altered.

Mullet on the west coast of Florida congregate in the winter months for spawning. These massed schools are thought by fishermen and others to migrate along the coast for a considerable distance. To determine whether fish migrate more during spawning season than during the rest of the year, movements of fish tagged before and during the spawning season and recaptured during and after the spawning season are compared with migrations of fish which were tagged at other times of the year and which were not free over the spawning season. More fish in the former group than in the latter were at large for long periods of time before recapture. To avoid the possible influence of the time elapsed since marking on the distance travelled, comparisons were made on the basis of fish free up to 90 days and fish free over 90 days (Table 4). In the first group 85.2 percent of those fish free during spawning and 93.4 percent of those not free during this period moved less than 20 miles. Among returns of the second group the percentages were 85.4 and 91.3 respectively. These differences are not statistically significant. It is apparent, therefore, that little increased tendency to migrate long distances is exhibited by fish during the spawning season. It should be remembered that this study concerns only mullet on the west coast of Florida for 1 year, and it is possible that different behavior may be shown in other regions or in future studies.

No consistent pattern of movement in one direction is shown by the tag returns so far. Of 67 returns of tagged fish recaptured 10 miles or more from the point of tagging, 32 had moved north or west and 35 south or east (Table 5). Furthermore, approximately equal numbers (16 and 18) had moved in each direction during the spawning season (October to February).

These results cast doubt on the commonly held view that Florida mullet make mass migrations over long distances. The large schools which can be seen moving during the spawning season may not move far, and the appearance of long migrations may be caused by a series of different schools moving at the same time. This view is held also by Kesteven (1942), who states for the Australian mullet, *M. dobula*, "The appearance of continuous movements is produced by migrations of independent schools and is probably more apparent than real." Kesteven also reports some long migrations of Australian mullet, the greatest being 450 miles, with another of 250 miles and a third of 100 miles.

A large proportion (66.0 percent) of all mullet recovered with accurate data had travelled over 25 miles. Most of these were captured 40 miles from the tagging point, as part of a large recovery of a single group caught at the same place on the same day. Some Australian mullet were recaptured months after tagging in the same area where they were released.

Observations of Rich (1926) on the North Carolina-Florida mullet also are in accord with the present findings. He concluded on the basis of returns from 3,000 fish tagged and released at Beaufort, North Caro-

TABLE 5.—*Direction of movement of 67 tagged mullet which migrated 10 miles or more—expressed by month of tagging.*

Month tagged	Number tagged	Number migrating north or west	Number migrating south or east
July.....	456	6	9
August.....	192	5	8
October.....	82	2	5
November.....	44	6	0
December.....	99	8	9
February.....	31	0	4
April.....	126	4	0
May.....	20	1	0
Total.....	1,050	32	35

lina, that migration was not extensive. Of the 31 fish returned all but one were taken in North Carolina waters. This exception was taken 52 days after liberation near Georgetown, South Carolina, 170 miles from the point of release. The longest time which elapsed between tagging and recapture in this experiment was 119 days.

ACKNOWLEDGMENTS

This study has been carried out as part of the fisheries program of the Florida State Board of Conservation by the Marine Laboratory of the University of Miami. The program has been greatly aided by the cooperation of a large number of fishermen and fish dealers, who are too numerous to name individually. Many of these men returned recaptured tagged fish and in several cases fishermen and dealers donated fish for tagging. This help is gratefully acknowledged, as is the assistance of fishermen who allowed the authors to tag mullet during their fishing operations.

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CHARACTERISTICS OF SPAWNING AREAS OF SHAD, *ALOSA SAPIDISSIMA* (WILSON) IN SOME VIRGINIA STREAMS¹

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ABSTRACT

In 1949 and 1950, a study of shad spawning areas by collecting eggs in plankton nets was undertaken in six Virginia rivers. The areas of maximum spawning were located in three rivers; some evidence of shad spawning was obtained in the others. The investigation included studies of environmental factors, including bottom topography, tidal currents, salinity, turbidity, and temperature. The time of spawning is described and the apparent natural mortality of eggs reported. The value of egg collections in providing information on time, location, and abundance of eggs is discussed.

INTRODUCTION

The shad, *Alosa sapidissima* (Wilson), is one of our most important commercial fishes, yet little is known of its spawning activities. Shad spawn in the spring in tidal rivers and estuaries, and according to Hildebrand and Schroeder (1927) spawning takes place soon after the fish reach fresh water. Smith (1907) maintains that shad prefer areas in rivers off the mouths of creeks, or in sounds off the mouths of rivers. Leim (1924) says that spawning in the Schubencadie River, Nova Scotia, takes place above the tidal portion of the stream in completely fresh water. The present study was undertaken to obtain more specific information on shad spawning areas in Virginia waters.

SAMPLING METHODS

Shad eggs drifting free in the rivers were collected in cone-shaped nets, 1 meter in diameter at the mouth and 3 meters long, made from netting of nylon marquisette having about 25 meshes to the inch. The nets were generally set in the current in pairs, one attached to an anchor at the bottom and one to a float at the surface (Figure 1). All nets were fished for intervals of 1 hour. The method of setting facilitated the handling of several pairs of nets at one time. The samples were preserved in 5 percent formalin.

Eggs were collected 2 successive years. During the spring of 1949 sampling was confined entirely to the tidal portion of the Pamunkey River (Figure 2, Table 1). The field work was undertaken between

¹Contributions from the Virginia Fisheries Laboratory No. 39.

February 27 and May 22 and collections were made at random along much of the river's course. In 1950, field work commenced on April 1 and continued until the end of May. Samples were taken in the Mattaponi, Chickahominy, James, Appomattox, and Rappahannock Rivers (Figure 2). Each river was sampled at intervals of from 3 to 5 nautical miles, with stations in the larger rivers being set at the greater intervals. Sampling stations extended from brackish water to

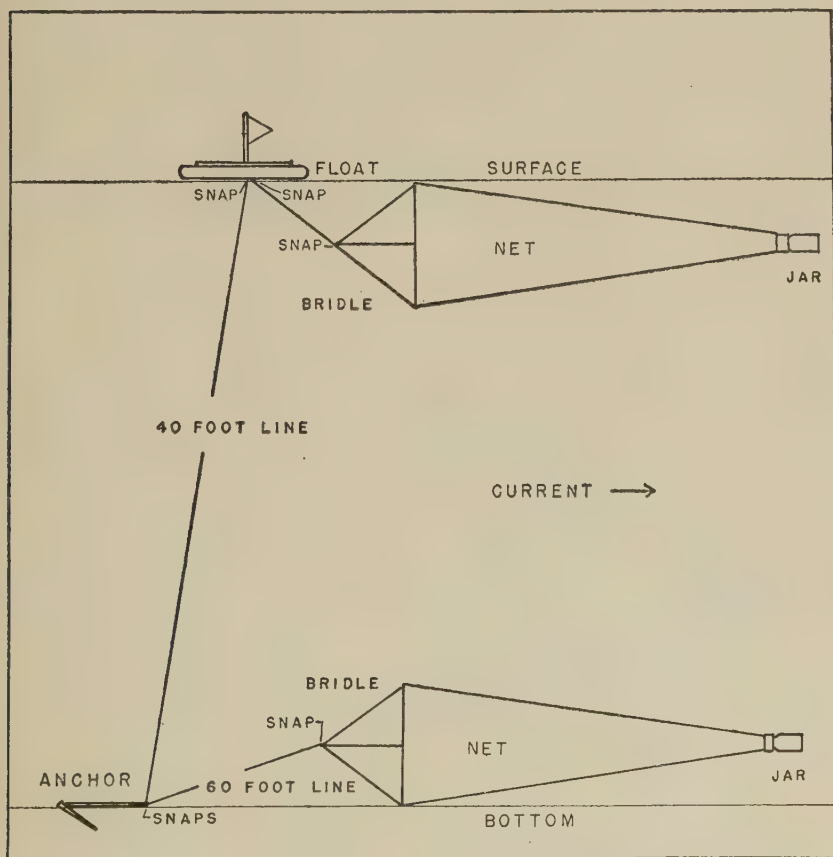


FIGURE 1.—Diagrammatic sketch of the manner in which plankton nets were set for the collection of shad eggs.

locations near the head of tidewater in the Mattaponi and Chickahominy Rivers. On the other streams it was necessary to discontinue sampling before the head of tidewater was reached in order to obtain at least partial coverage during the spawning season. Stations occupied



FIGURE 2.—Virginia rivers where shad spawning was studied. See Table 1 for the names of sampling localities indicated by letters on the map.

and their distances upstream from Chesapeake Bay are included in Table 2. More than 450 samples containing a total of 2,469 shad eggs were collected. Measurements of water temperature, currents, salinity, and turbidity supplemented most of the plankton collections.

SPAWNING GROUNDS

Spawning grounds were located primarily by observation of the relative numbers of eggs collected in the nets. Since current velocities appear to influence the numbers of eggs taken (page 92), only those samples collected at velocities of from 1 to 2 feet per second were used in estimating relative egg abundance. Shad spawning areas have also been located by noting the incidence of "spawners," i.e., fish with running roe, in commercial catches.

Pamunkey River.—As indicated in Table 3, shad eggs were most abundant in the area from Lester Manor to Gregory Bar, a distance of 7 miles. The few eggs collected upstream and downstream from these points indicate that spawnings of much less intensity may take place for at least 7 miles in either direction from the major region. Eggs were not collected either in the vicinity of brackish water or from waters near the head of the tide.

Mattaponi River.—The Mattaponi River was sampled from April 25 to 30, 1950. This period was thought to be the height of the spawning season. Examination of more than 100 samples indicated that eggs were most abundant at Mattaponi and Sandy Point (Table 4). No shad eggs were collected below Mattaponi but a few were taken upriver as far as Line Tree Bar, 10 miles above Sandy Point.

Chickahominy River.—The two shad eggs collected during the sampling period, May 5 to 8, 1950, were taken near Watts Point. Low current velocities hindered sampling further upstream. Spawning shad, many of which are utilized by a hatchery in the Lanexa area, are found in commercial catches from Big Marsh Point upriver at least as far as Lanexa. This occurrence suggests that the major spawning effort takes place in this region. A dam at Walkers, 5 miles above Lanexa, was completed during 1943. It was feared by many that the dam would interfere seriously with, if not eliminate the Chickahominy shad run. No decline has been noted because it appears that the major spawning area is below the dam.

James River.—Two eggs were collected from the James River a few miles below Hopewell and one egg near Turkey Island Cutoff, a few miles above that city from May 9 to 10, 1950. Interviews with local fishermen failed to produce information regarding the catch of spawners, although the Hopewell area is in the region of shad spawning.

Appomattox River.—A few samples were taken in the Appomattox River on May 10 at Point of Rocks, 5 miles above Hopewell. These samples contained two shad eggs which were collected from nets set

TABLE 1.—Location of sampling stations on six¹ Virginia rivers shown in Figure 1.

Station	Rappahannock River	Mattaponi River	Pamunkey River	Chickahominy River	James River
A.....	Mallory Point	West Point	West Point	Barretts Point	Jamestown Island
B.....	Island Point	Muddy Point	Lee Marsh	Nettles Creek	Dancing Point
C.....	Layton Landing	Chelsea	Devils Reach	Shipyard Landing	Dunmore
D.....	Ketch Point	Boardley	Island Reach	Watts Point	Windmill Point
E.....	Owl Hollow	Foxes	Cumberland Reach	Big Marsh Point	Jordon Point
F.....	Wilnot	Courthouse Landing	Lester Manor	Lanexa	Hopewell
G.....	Portobago Bay	Mattaponi	Lane Reach	Walkers Dam	Turkey Island
H.....	Port Royal	Sandy Point	Rockahock		
I.....		Rickahock	Gregory Bar		
J.....		Peavine Island	Buckland Bar		
K.....		Line Tree Bar	Hogan Bar		
L.....		Pointer Landing	Spring Bar		
M.....		.....	Bassett Bar		

¹Appomattox River was sampled only at Point of Rocks.

TABLE 2.—Distances from Chesapeake Bay of stations occupied during shad investigations—points of special significance¹ indicated in parentheses ().

Miles from Chesapeake Bay	Pamunkey River	Mattaponi River	Chickahominy River	James River	Rappahannock River
27-28.....	West Point	West Point			
29-30.....	Lee Marsh	Muddy Point			
31-32.....	(B)	Chelsea			
33-34.....	Devil Reach	Boardley (B)			
35-36.....		Foxes		Jamestown	
37-38.....		Courthouse Ldg. (F)		(B)	Tappahannock
39-40.....		Mattaponi (SF)	Barretts Point (B)	Dancing Point	Mallory Point (B)
41-42.....		(SF)	Nettles Creek		Island Point
43-44.....	Island Reach	Sandy Point (SF)	Shipyards Landing		Layton Landing
45-46.....	Cumberland Reach (SF)	Rickahock (SF)	Watts Point (SF)		Ketch Point
47-48.....	Lester Manor (SF)	Peavine Island (F)	Big Marsh Point (SF)	Dunmore	Owl Hollow
49-50.....	(SF)	(F)	(SF)		Windmill Point (F)
51-52.....	Rockahock (SF)	Line Tree Bar (F)	Lanexa (SF)		(F)
53-54.....		Pointer Landing	Walkers Dam (F)	Jordon Point (EF)	Wilmot (F)
55-56.....	Gregory Bar (SF)			Hopewell (F)	Portobago Bay (EF)
57-58.....				Turkey Island (EF)	(F)
59-60.....	Buckland Bar				Port Royal (F)
61-62.....	Hogan Bar				
63-64.....	Spring Bar				
65-66.....	Bassett Bar				
67-68.....					

¹(B)—Approximate boundary between fresh and brackish water.

(S)—Area of shad spawning as interpreted in this paper.

(F)—Region of extensive flats.

(E)—Location where some spawning occurred.

at the mouth of the old Walthal Channel, a branch of the Appomattox in which shad are sometimes caught. The greater portion of the Appomattox between Hopewell and Petersburg, particularly in the vicinity of Petersburg, is heavily polluted with industrial and domestic wastes, and therefore this river is probably of little importance as a shad spawning region.

Rappahannock River.—The Rappahannock River collections of 1950 contained no shad eggs. This river was visited rather late in the spring, from May 17 to 21, although well within the time and temperature range at which eggs were collected in the Pamunkey River during the preceding season. Large masses of filamentous algae clogged the nets and undoubtedly reduced their efficiency. A few clupeid larvae, some of which appear to be shad, were obtained in the Portobago Bay samples. Fishermen reported that spawning shad are often taken in that section of the river.²

EFFECT OF PHYSICAL AND CHEMICAL FACTORS ON SPAWNING

Bottom topography.—Each river may be divided roughly into three rather homogenous sections on the basis of its bottom topography. The lower part consists mostly of deep channels with few shoals and relatively steep banks. Further upriver channels are present but much of the area consists of shallow flats, often only a few feet below the surface. Beyond this section the river is, for the most part, deeper with rather precipitous banks. The locations of these various sections are indicated in Table 2. Spawning shad apparently prefer river sections dominated by extensive flats.

Bigelow and Welsh (1925) stated that shad spawning occurs over the shallow flats, while Smith (1907) concluded that although most spawning activity takes place over the flats, it may occur anywhere in the rivers. In the present study egg collections over the shallower flats yielded few eggs. Since currents at such points were often less than 1 foot per second and sometimes insufficient to extend the nets, towing was tried, but still no eggs were obtained. It seems probable that in still waters the eggs sink to the bottom and are therefore available to nets for only a short period.

That shad frequently spawn in channel areas near the flats is indicated by the collection of newly-spawned eggs from such locations. It is not known whether the greater spawning effort takes place in the deeper water near the shallows or on the shallows themselves. It is possible that flats are more important as nursery areas for the young fish than as locations necessary for spawning.

Currents.—Tidal currents were measured at the surface using either an Ekman current meter or a weighted drift bottle. Studies of the surface and bottom currents in the tidal fresh water area of the Rap-

²A survey conducted on the Rappahannock River in 1951 indicated that Portobago Bay was probably the most important shad spawning area in that river.

TABLE 3.—Numbers of shad eggs collected from surface and bottom of the Pamunkey River at various stations—1949¹.

Item	Devil Reach	Island Reach	Cumberland Reach	Lester Manor	Lane Reach	Rockahock	Gregory Bar	Buckland Bar	Spring Bar
Surface									
Number of hours....	7	12	6	7	11	25	6	4	4
Number of eggs....	1	0	0	0	1	193	36	0	7
Eggs per hour.....	0.1	0.0	0.0	0.0	0.1	7.7	6.0	0.0	1.8
Bottom									
Number of hours....	7	12	6	10	11	28	6	4	4
Number of eggs....	0	2	3	96	9	1,130	452	7	4
Eggs per hour.....	0.0	0.2	0.5	9.6	0.8	40.4	75.3	1.8	1.0

¹Samples are from 1-hour sets with nets of 1-meter diameter anchored in a current of 1 to 2 feet per second.

TABLE 4.—Numbers of shad eggs collected from surface and bottom of the
Mataponi River at various stations—1950¹.

Item	West Point	Muddy Point	Chelsea	Boardley	Clifton Landing	Foxes	Court House Landing	Matta- poni	Sandy Point	Ricka- hook	Peavine Island	Line Tree Bar
Surface												
Number of hours...	0	4	1	1	3	5	3	4	3	1	0	1
Number of eggs...	0	0	0	0	0	0	0	1	13	1	0	0
Eggs per hour....	.....	0.0	0.0	0.0	0.0	0.0	0.0	0.2	4.3	1.0	.....	0.0
Bottom												
Number of hours...	4	4	4	4	2	6	7	12	6	4	4	4
Number of eggs...	0	0	0	0	0	0	0	203	40	23	0	7
Eggs per hour....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.9	6.6	5.8	0.0	1.8

¹These are 1-hour samples with nets of 1-meter diameter anchored in a current of 1 to 2 feet per second.

TABLE 5.—The numbers of shad eggs taken from the most productive stations on the Pamunkey River in samples collected at several different temperatures¹.

Item	Temperature (degrees C.)								
	6—7.9	8—9.9	10—11.9	12—13.9	14—15.9	16—17.9	18—19.9	20—21.9	22—23.9
Surface									
Number of hours....	6	5	0	6	9	6	16	0	22
Number of eggs....	0	2	0	7	167	38	36	0	124
Eggs per hour.....	0.0	0.4	.....	1.2	18.6	6.3	2.2	.....	5.6
Bottom									
Number of hours....	6	0	0	8	16	8	14	5	15
Number of eggs....	0	0	0	234	478	260	496	0	214
Eggs per hour.....	0.0	.....	.....	29.2	29.5	32.5	35.5	0.0	14.3

¹One-hour samples collected with nets of 1-meter diameter anchored in a current of 1 to 2 feet per second.

pahannock River during the spring have indicated that surface velocities exceed bottom velocities by an average of 0.26 feet per second. Sampling was undertaken only during periods of flood or ebb tides. All shad spawning observed took place within the limits of tidal influence. Current velocities on the spawning areas varied from zero at slack water to slightly more than 3 feet per second. The tidal current transports drifting shad eggs upstream and downstream, the net effect being a slight downstream displacement related to river runoff.

Shad eggs are slightly heavier than water (shad eggs preserved in 5 percent formalin sink at a rate of 2.4 feet per minute in water of 25.8° C.). They may be supported by currents in several ways. Sver-

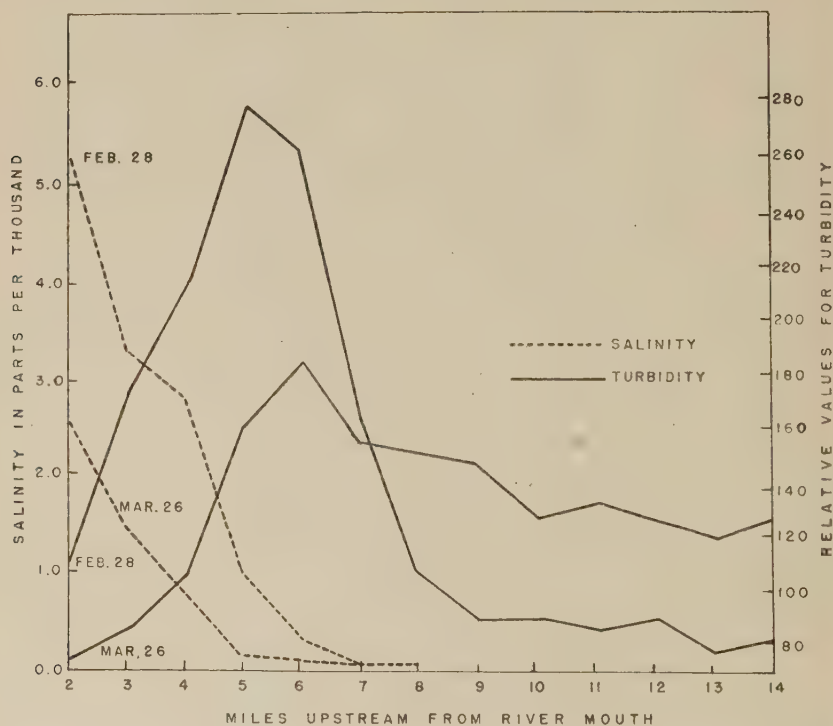


FIGURE 3.—Salinity and turbidity data taken on two cruises up the Pamunkey River in 1949. The samples were collected at approximately high tide. Turbidity values are in scale readings of a Klett-Summerson photoelectric colorimeter with a 40-millimeter cell and a K.S. 40 filter.

drup, Johnson and Fleming (1942) point out that the distance particles can be carried depends on their settling velocity, the velocity of the current, and turbulence. Dr. Donald W. Pritchard (personal com-

munication) has indicated that, since water velocities near the surface are generally greater than those near the bottom, the resultant force at intermediate depths is directed upward. This force would also aid in keeping shad eggs in suspension. It appears quite probable that many eggs collected in the bottom nets may be merely rolling along the bottom.

Salinity.—Salinity determinations were made from samples taken at both surface and bottom. The samples were titrated with silver nitrate, and chlorinity readings were converted to salinity using Knudsen's tables. Surface and bottom salinities were averaged to give a single value. The samples revealed that spawning invariably took place in fresh water.³ In the various rivers the major spawning area is situated at varying distances above brackish water (Table 2). The downstream limit of fresh water varies in a single river, as pointed out by Galtsoff, Chipman, Engle, and Calderwood (1947). Although shad appear to spawn only in fresh water there is no evidence that the spawning areas are located at a fixed distance above brackish water.

Turbidity.—Most Virginia tidewater rivers, especially in spring, are characterized by turbidities much greater than those in the waters of Chesapeake Bay. Generally, the higher turbidities were encountered in the regions where fresh river water mixed with the saline water from the Bay (Figure 3). These areas are indicated in Table 2. Therefore, shad migrating to their spawning grounds must pass through these maximum turbidities.

Water temperature.—Bigelow and Welsh (1924) assert that the temperature must be from 10° to 13° C. before shad will enter a stream for spawning. It has been reported elsewhere (Anon., 1946) that a temperature of 12° C. is necessary before spawning occurs. Water temperatures were taken at both surface and bottom with a reversing thermometer. The differences, seldom more than a few tenths of a degree C., were averaged to give a single value. In the Pamunkey River during 1949, the range of temperature through the sampling period was 6.4° C. to 23.9° C. Eggs were not taken in abundance until the temperature had reached 12.0° C. although a few were collected at lower temperatures. The relationship between temperature and abundance of eggs is presented in Table 5. Spawning appears to take place over a wide range of temperature, but the median spawning temperature was between 16° and 17° C.

TIME OF SPAWNING

The approximate age of shad eggs may be estimated from their known rate of development at various water temperatures. A series of shad eggs held in a hatchery and preserved at known time intervals after spawning was obtained from James Sykes of the U. S. Fish and Wild-

³Leim (1924) showed experimentally that shad eggs hatched and larvae developed better in brackish water.

life Service. These eggs had been reared at a temperature of 16° to 17° C., which is close to the average water temperature during the period that the Pamunkey River collections were made, and corresponds with the median temperature per egg in the field collections. The stages of development attained at various time intervals are summarized in Table 6.

Single samples or series of samples collected from the rivers did not contain sufficient numbers of live eggs to be of much value in age studies. Therefore, all the live eggs collected during the more inten-

TABLE 6.—*The approximate stage of development of shad eggs obtained at various intervals from a hatchery sample maintained at temperatures of 16° to 17° C.*

Stage of development	Designation	Age in hours
One cell.....	I	2
Many cells.....	II	4
Blastula.....	III	6
Gastrula.....	IV	13
Primitive streak.....	V	$20\frac{1}{2}$
Early embryo.....	VI	$25\frac{1}{2}$
Embryo with tail attached to yolk.....	VII	38
Embryo with tail free from yolk.....	VIII	42
Hatching.....		96

sive study of the Pamunkey were grouped together and arranged into three series according to time of day, as follows: 6:00 a.m. to 12:00 a.m., 12:00 a.m. to 6:00 p.m., and 6:00 p.m. to 12:00 p.m. (little sampling had been done between midnight and dawn). Only a small percentage of the live eggs collected in the morning were in the one-celled stage or less than 3 or 4 hours old (Figure 4). In the afternoon 28 percent of the eggs, and in the evening 35 percent were in this stage of development. The proportions of eggs having from two to many

TABLE 7.—*Percentages of some developmental stages of shad eggs found in surface and bottom samples from the Pamunkey River in 1949.*

Stage of development	Percentage of eggs in surface samples	Percentage of eggs in bottom samples
One cell.....	40.1	29.7
Two cells to many cells.....	46.2	43.9
Blastula and gastrula.....	8.3	18.8
Primitive streak to hatching.....	5.3	7.6

cells (from 4 to 6 hours old) appeared to follow the same general pattern. This observation seems to indicate that spawning in the Pamunkey River takes place during all hours of the day and night, although possibly it is somewhat more intense in the period from noon to midnight.

Bottom samples contained about six times as many eggs per hour of sampling as did those taken from the surface. However, spawning probably occurs more generally near the surface, since a greater percentage of early stage eggs was taken in the surface samples (Table 7).

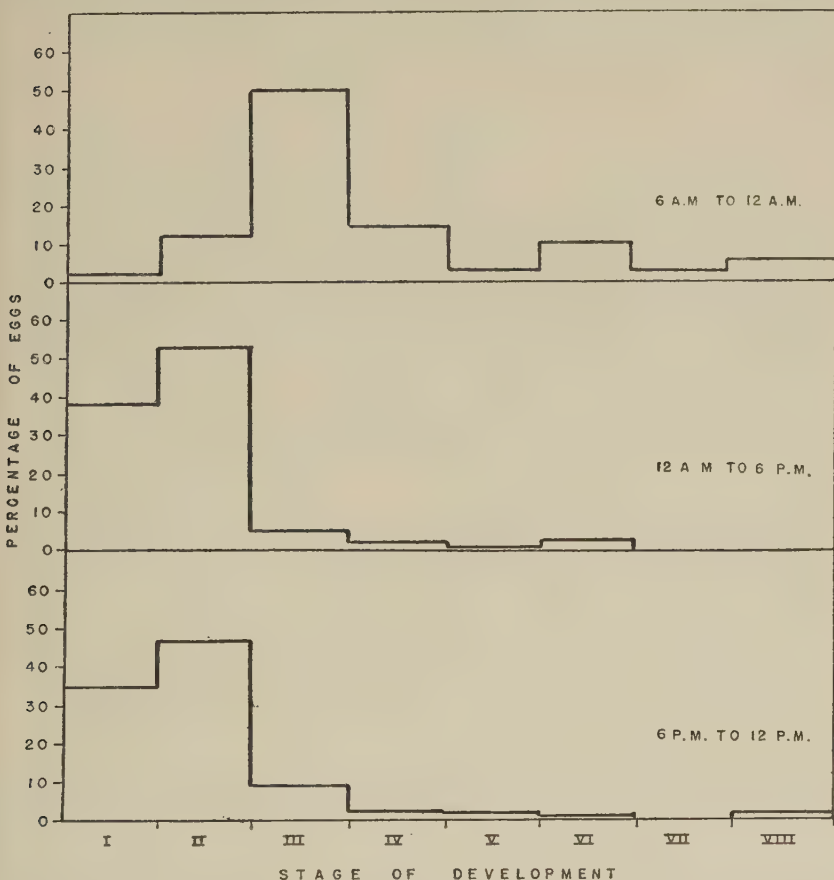


FIGURE 4.—The percentages of shad eggs of various stages of development in the catch during different periods of the day. Roman numerals refer to developmental stages listed in Table 6.

EGG MORTALITY

Almost two-thirds of the shad eggs collected in Virginia rivers were dead.⁴ It would be hazardous to draw conclusions at this time because there is little information regarding the availability of live as compared

⁴An egg was considered dead if the yolk had coagulated or had adhered to the vitelline membrane instead of drifting free within.

with dead eggs or the effect of the nets on mortality. It is interesting to note that 66 percent of the Pamunkey River eggs were dead as compared with 80 percent from the Mattaponi. Shad hatchery men often separate dead from live shad eggs by adjusting water flow so that the dead eggs rise to the surface where they may be skimmed off. In this study dead eggs were relatively more frequent in bottom samples (63 percent at the surface, 68 percent at the bottom).

CONCLUSIONS

Collections obtained by the method used in this study may be expected to disclose the time and place of shad spawning, and provide a rough index of egg abundance. Although previous investigators have not been successful in collecting shad eggs during daylight hours, in the present study eggs were collected with almost equal facility during both day and night. It is not possible to obtain precise information on absolute abundance, however. The number of eggs collected in a spawn-

TABLE 8.—*Numbers of shad eggs collected at different current velocities in the four most productive stations on the Pamunkey River.*

Item	Current velocity (feet per second)		
	0.0—0.9	1.0—1.9	2.0—2.9
Surface			
Number of hours	10	38	12
Number of eggs	0	168	204
Eggs per hour	0.0	4.4	17.3
Bottom			
Number of hours	6	41	12
Number of eggs	1	1,012	616
Eggs per hour	0.2	24.6	51.3

ing area appears to vary directly with the current velocity (Table 8). Temperature may have some effect on the number of eggs present in the water at any one time by altering the rate of development. Ryder (1887) observed that hatching took place in 17 days at a temperature of 12.2° C., while at 23.3° C. only 3 days were required. Thus individual eggs would be present more than five times as long at the lower temperatures. This point must be considered in estimating the absolute abundance of eggs.

Because large quantities of organic debris are usually taken in the nets, the task of sorting out eggs and larvae is laborious. A small proportion of the eggs is undoubtedly missed in the sorting process, and this proportion may vary in relation to the amount and type of debris present. Measures of egg abundance therefore may be somewhat low.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to the many people who assisted in this study. Special thanks are due to former Director Dr. Nelson Marshall, present Director Dr. J. L. McHugh, and the entire staff of the Virginia Fisheries Laboratory. Dr. Alfred Armstrong, Dr. Roy Ash, and Ernest Tresselt, of the College of William and Mary, Louella Cable and James Sykes, of the U. S. Fish and Wildlife Service, and members of the staff of the Chesapeake Bay Institute gave freely of advice and technical assistance. The author's wife, Kathleen Massmann, made the nets and offered assistance and encouragement throughout the study.

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DISEASES AND PARASITES OF THE SEA LAMPREY, *PETROMYZON MARINUS*, IN THE LAKE HURON BASIN

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ABSTRACT

Sea lampreys from the Lake Huron basin carried no external parasites and showed a fairly low degree of infection by internal parasites. The material examined represented three life-history stages of the sea lamprey. Recently transformed downstream migrants (215 specimens) harbored only nematodes belonging to the genus *Camallanus*. The percentage of infection was 2.3. Active feeders from the lake (29 lampreys) revealed the highest degree of parasitism (31.0 percent) with the following parasites present: *Echinorhynchus coregoni* Linkins; *Triacnophorus crassus* Forel; and *Camallanus* sp. Among the 257 sexually mature upstream migrants (14.8 percent infected) *Echinorhynchus coregoni* and *E. leidy* Van Cleave were the most common. Only occasional nematodes and cestodes were found, which fact indicates a failure of the lamprey to carry these parasites to the end of its natural life. Of the parasites observed, only the nematodes gave evidence of serious damage to the host. The study suggests that the role played by parasites in the natural control of the sea lamprey in its new habitat in the upper Great Lakes is of minor importance.

INTRODUCTION

The sea lamprey, *Petromyzon marinus*, can be added to the list of animals which have been introduced or have invaded a habitat where endemic forms offer little or no control by competition, disease, parasitism, or predation. Without a natural or biotic control its numbers have increased to a point where the animal, being parasitic itself, has visited such destruction upon the fisheries of the Great Lakes that it will have few equals in history.

To combat this recognized menace effectively all phases of its life history and biology must be explored with consideration given to any point that appears vulnerable to an attack. This study represents one phase of a comprehensive program of such investigations currently being carried on by the U. S. Fish and Wildlife Service's Great Lakes Fishery Investigations. Presented herein are data relative to the incidence of diseases and parasites among samples of the sea lampreys at various life-history stages and the comparative degree of infection among spawning migrants in 3 consecutive years.

MATERIAL AND METHODS

The majority of the sea lampreys collected for this study were captured in experimental control devices operated in various streams in the northern part of the Lower Peninsula of Michigan. A total of 257 sexually mature upstream migrants were obtained in 1949 and 1950 from a weir and trap installed in the Ocqueoc River, Presque Isle County, Michigan. Two hundred fifteen downstream migrants (recently metamorphosed) were taken at random from runs captured in an inclined-plane trap operated in the Carp Lake River, Emmet County, and in fyke nets fished in the Ocqueoc River in 1950 and 1951. In addition, 29 actively feeding sea lampreys became available during the period of study. These lampreys were attached to fish taken in trap nets set in the inshore waters of northern Lake Huron. Comparative data on the degree of parasitization of spawning migrants captured in 1948 in this area have been taken from Applegate (1950).

Inasmuch as organizational effort was almost completely confined to the operation of experimental control devices during the period of upstream migration, it was necessary to preserve the material collected until the time of examination. Quick-freezing and holding in cold storage proved to be satisfactory. For the most part, the downstream migrants and the active feeders from the lake were held alive until examined. At most this period of holding did not exceed 3 days.

Each animal was examined for external parasites, wounds, or any abnormality which might be revealed under macroscopic observation. The complete digestive tract was then removed for examination and the body cavity and internal organs were carefully inspected. In the preparation and preservation of the material taken from the sea lampreys, laboratory techniques commonly prescribed for the individual parasites were followed. Some tumor-like growths and abnormal organs were sectioned whereas others were macerated and examined microscopically.

PARASITIZATION OF SEA LAMPREYS AT DIFFERENT
LIFE-HISTORY STAGES

The sea lamprey begins its parasitic life after an apparently harmless existence as a blind, toothless ammocete in the mud beds of its parent stream. It appears to be an exceedingly healthy individual, and tends to remain comparatively so until the physical degeneration begins which subsequently results in its death after spawning. In the material examined no recognizable bacterial, virus, or sporozoan infection was found.

Although an occasional specimen revealed external body wounds which were obviously of mechanical origin, none exhibited secondary infections. No significant incidence of developmental or structural abnormalities was found. One downstream migrant had a body which

appeared to end posteriorly at the midpoint of the second dorsal fin. By comparison, its body should have been approximately 25 percent longer. Surprisingly enough, this abnormality did not seem to impair the locomotion of the animal to any great extent.

In general, the sea lamprey population in the Lake Huron basin has a comparatively light infection and a fairly uniform composition of internal parasites. The most common parasites are adult *Acanthocephala* which inhabit the digestive tract. Two species were found, *Echinorhynchus coregoni* Linkins and *E. leidy* Van Cleave.¹ *E. coregoni*, by far the most common, was found throughout the entire length of the digestive tract with a few individuals located almost at the anal opening. In no specimen was the infection heavy enough to be considered harmful or severe. The greatest number of *Acanthocephala* found in a single sea lamprey was 15; another sea lamprey contained 8; three had 7; and the remaining lampreys had from 1 to 4 parasites, most commonly 1 or 2. In a sample of 100 sea lampreys from the 1948 spawning run examined by Applegate (1950), only *E. coregoni* was found, and in no case did a single lamprey harbor more than three of the parasites.

Very little is known of the life histories of *E. coregoni* and *E. leidy* and the mode of infestation is not at all obvious, especially in view of the mechanics involved in the feeding behavior of the sea lamprey. The two species often occur in mixed infections and the adult *E. coregoni* has been commonly reported from the coregonid and other freshwater fishes of North America and Europe. Although the hosts of the adult worms are believed to be preferred prey for the sea lamprey, the transfer of adult *Acanthocephala* appears unlikely. It would seem that an encysted stage must become available to the sea lamprey. H. J. Van Cleave² states that some species of *Acanthocephala* must reach a certain stage of maturity in their anthropod host before development in the fish host will proceed normally. Otherwise, they tend to encyst in the mesenteries of the fish. They could be taken by the lamprey directly in this encysted stage, or possibly by ingestion of amphipods and copepods.

Of the total number of sea lampreys examined, only three individuals harbored cestodes. An upstream migrant contained a single specimen, and two individuals captured in Lake Huron contained a total of three specimens. With the possible exception of one which was found embedded in a small cyst-like growth, these cestodes were identified as *Triaenophorus crassus* Forel.³ The specimen from the abnormal growth was almost completely disintegrated except for portions of the scolex but the remains appeared to be those of *T. crassus*. The second juvenile stage, or the plerocercoid larva of *T. crassus* is frequently found en-

¹Identified by Dr. H. J. Van Cleave of the University of Illinois.

²Personal communication.

³Identification verified by Leonard N. Allison, Fisheries Pathologist, Michigan Department of Conservation.

cysted in the flesh of the coregonid fishes (Van Cleave and Mueller, 1934). Thus the mode of infestation appears fairly obvious. It is believed that this cestode would not reach sexual maturity in the sea lamprey, an unnatural final host. In the sample taken during the 1948 run, Applegate (1950) found a plerocercoid larva of *T. crassus*. He also found a single, immature specimen of *Abothrrium* sp. and the unidentifiable remains of another cestode.

It appears that nematodes produce the most serious pathological disturbance. In all lampreys which contained them, a tumor-like growth or a severely damaged organ existed. Unfortunately, only females belonging to the genus *Camallanus* (identified by L. N. Allison) were found. Positive identification of the species was not obtained.

In addition to the general observations recorded above, the mode and degree of infection and/or parasitization differed among the various life history stages as follows.

Downstream migrants.—In addition to the 215 newly transformed lampreys (Table 1), three selected specimens were examined that had a greatly swollen area just posterior to the branchial region. Dissection revealed that two of the lampreys had severely infected livers while the third had a large tumorous growth one-half inch long and one-fourth inch in diameter, attached to the gonads just behind the liver. Both livers were greatly enlarged—one approximately four times and the other about three times normal size. The livers were vacuolated and of a homogeneous consistency. The only portion of either liver which appeared normal was the very tip of the lobe. A nematode (*Camallanus* sp.) was removed from one of the livers and from the tumorous growth, but nothing was found in the other liver.

Five additional individuals with infected livers were discovered in the sample of 215 young sea lampreys. All were comparable in appearance to those described above except that the diseased organs were not as severely enlarged. Four of the abnormal livers contained one specimen each of *Camallanus* sp. Nothing was found in the other. Two more young lampreys were found with tumor-like growths. In one specimen a small cyst-like growth attached to the wall of the body cavity yielded no causative agent while a fairly large gelatinous mass found on the outer intestinal wall of the other lamprey contained a nematode (*Camallanus* sp.). Thus of the 215 downstream migrants examined, 5 or 2.3 percent were parasitized, while 2 more contained abnormalities which were probably the result of parasitism.

Upstream migrants.—Of the 257 sexually mature, upstream migrants examined, 123 were collected in 1949 and 134 in 1950. No external parasites were found, but 22, or 17.9 percent of the 1949 run and 16, or 11.9 percent of the 1950 run contained one or more internal parasites. As was mentioned previously, *Echinorhynchus coregoni* was by far the most common parasite present. Only one cestode and one

nematode were found in the entire 1949 collection of spawning migrants (Table 1). The cestode, *Triaenophorus crassus*, was found in the digestive tract of one lamprey and in another individual the nematode, *Camallanus* sp., was in the periphery of a large (1 inch long and $\frac{1}{2}$ inch in diameter) tumor which was attached to the gonads just posterior to the liver. A third specimen had a similar growth, also

TABLE 1.—Percentage of sea lampreys infected with internal parasites and abnormal growths with no detectable causative agent.

Stage and date of collection	Number examined	Percentage parasitized	Percentage parasitized			Percentage with abnormal growths
			Acanthocephalans	Nematodes	Cestodes	
Upstream migrants						
1948 ¹	100	20.0	17.0	.....	3.0	.....
1949.....	123	17.9	16.3	0.8	0.8	1.6
1950.....	134	11.9	11.9	.....	.....	0.7
Lake feeders						
1950—51.....	29	31.0	13.8	10.3	6.9	3.5
Downstream migrants						
1950—51.....	215	2.3	.....	2.3	.....	0.9

¹Applegate (1950).

attached to the gonads, for which no causative agent was determined. Similarly, nothing was found in 2 small ($\frac{1}{4}$ inch in diameter), colorless, cyst-like growths on the outer intestinal wall of another sea lamprey.

The 1950 sample of spawning migrants was less severely infected than either the 1949 sample or the collection examined by Applegate (1950) from the 1948 run. Parasitization was restricted solely to Acanthocephala and only one individual with a diseased organ was discovered. In this specimen the liver exhibited an abnormality which was generally comparable to those found in the downstream migrants. It was slightly enlarged and covered with small, whitish nodules. Sectioning failed to reveal any parasites, but it appeared likely from comparisons with similar diseased organs among downstream migrants that a nematode was the causative agent.

Actively feeding lampreys from the lake.—Only 29 actively feeding sea lampreys collected directly from the lake became available during the study period. Of the group, 9 or 31 percent contained parasites or the identifiable remains of a parasite. Four or 13.8 percent of the individuals carried *Echinorhynchus coregoni*; 3 or 10.3 percent contained nematodes, *Camallanus* sp.; and 2 harbored cestodes, *Triaenophorus crassus*. One of these cestodes was mentioned previously as embedded in a cyst-like growth and as being almost completely disintegrated. One other lamprey contained two cestodes.

The nematodes, as before, were found in tumor-like growths. Along with the growth which yielded a nematode in one sea lamprey were two more growths that were comparable in every way to those containing the nematodes. One was located on the outer intestinal wall and the other was on the wall of the body cavity. These two growths yielded three unidentifiable fragments which appeared to be the walls of cysts formed by some animal which had subsequently disintegrated. Microscopic examination of the fragments failed to reveal any organization of tissue.

Actively feeding lampreys in aquaria. — Sea lampreys confined in 55-gallon glass aquaria show a fairly high degree of susceptibility to infection from fungus, *Saprolegnia parasitica* Coker, and to the ectoparasitic protozoan, *Ichthyophthirius multifiliis*, which is commonly referred to as "the itch." Only one outbreak of "the itch" occurred in more than 14 months of continuous operation of the aquaria. The disease is reported to be common and widespread and to attack many species of fish, especially those of ponds. The attack by *Ichthyophthirius multifiliis* was severe and at least five aquarium-held lampreys died as a result of heavy infection. Commonly prescribed methods of control (Davis, 1947) have proved effective in combating both diseases. Neither of the diseases was found on any of the individuals taken from the "wild."

CONCLUSIONS

Three separate patterns of parasitism were encountered in the three life-history phases of sea lampreys examined (Table 1). Although the number of active feeders from the lake was too small to yield conclusive information for that group, there is evidence for a definite trend in the pattern of parasitization as the lamprey passes through its several stages of existence. A very small percentage of the downstream migrants were parasitized and then only by a single species of nematode. In the second group, the active feeders, a relatively high percentage (nearly one-third) of the sample was parasitized and representatives of cestodes and nematodes as well as acanthocephalans were encountered. The third group (upstream migrants), revealed a sharp decrease over the active feeders in the percentage of individuals parasitized. However, the percentage of upstream migrants infected with *Acanthocephala* was comparable to the percentage in active feeders. The failure of the sea lamprey to carry the majority of the nematodes and cestodes to the end of its natural life brings out one of the most interesting points of the study.

There are at least two means whereby cestodes encountered by the sea lamprey may disappear before the time of upstream migration. One possibility is that since the sea lamprey is an unnatural final host, the worm dies and is passed out. The other possibility lies in the fact that the sea lamprey ceases to feed prior to ascending the streams

to spawn. With the cessation of feeding, physical degeneration begins which almost immediately affects the gross and microscopic anatomy of the digestive tract. The intestine is usually a fraction of its normal size and is nearly empty at the time of upstream migration. It is believed that many of the tapeworms disappear during this period. Furthermore, the almost completely disintegrated remains of the cestode found in a small cyst-like growth may well indicate the mode of disappearance. Comparable growths were discovered in which no causative agent was found.

The situation is somewhat different in the nematodes. They are probably the most important of the parasites, causing the most serious pathological disturbances in the sea lamprey. For the most part they are acquired while the animal is still inhabiting its larval beds. It also seems that this parasite has a preference for invading the liver. The condition of this organ resulting from the invasion is such that in all cases it appeared incapable of functioning properly and could result only in the ultimate death of the sea lamprey. If the nematodes attack the gonads, kidney, or wall of the body cavity, the so-called tumorous growths result.

The tumors and cyst-like growths can possibly be compared to a fibrosis or to an adventitious cyst. Although their presence may be harmful or painful to the sea lamprey, their actual pathological effect is questionable.

It appears that the role played by disease and parasitism in the natural control of this animal in the Great Lakes is so insignificant that it is of no importance. There are no indications derived from this study of any natural control arising from this source in the near future.

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FURTHER STUDIES ON FACTORS DETERMINING TISSUE LEVELS OF SULFAMERAZINE IN TROUT

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ABSTRACT

There is considerable variation in the tissue level of sulfamerazine among individual trout in a treated population. This fact may be the reason why prolonged sulfonamide therapy sometimes fails to free all trout from *Bacterium salmonicida*. The quantity of food given with a standard dosage of sulfamerazine has a pronounced effect on the tissue concentration of sulfamerazine; the concentration increased when the quantity of food decreased. It appears therefore, that trout should be fed at a rate very closely adjusted to their optimum feeding requirements for the best practical results. The start of treatment with high initial doses of sulfamerazine had no effect on the tissue concentration sustained by the maintenance dosage. The relative distribution of sulfamerazine in various organs and tissues of rainbow trout was about the same as in brown and brook trout. The only difference noticed was the lack of peak levels of short duration between the 8 and 10 days of treatment, which is characteristic for brook and brown trout.

INTRODUCTION

The initial studies on the distribution of sulfonamides in trout tissues were described in a previous paper (Snieszko and Friddle, 1951). These investigations were designed to gain a better understanding of the therapeutic action of sulfonamides which are being used in the treatment of furunculosis and certain other bacterial fish diseases. The present study is an extension of the original work. Sulfamerazine was the only sulfonamide tested in these experiments because it is the drug of choice in chemotherapy of fish diseases. Limitations in time and facilities made it impossible to carry out parallel tests with other sulfonamides. The methods of investigations were the same as those previously described, and all trout used were maintained in water having a temperature of 12° to 14° C. (53° to 57° F.).

VARIATION IN THE TISSUE CONCENTRATION OF SULFAMERAZINE

In all previous tests described, sulfamerazine levels were determined for composite samples made from several fish. In this experiment the determinations were made for individual trout to determine the degree of variation in the sulfonamide tissue level. The trout used in these experiments were taken at random from a treated population.

Fingerling brook trout (average weight 53 grams) were distributed in 4.5-kilogram lots in two troughs. They were fed twice daily at a rate of 4 percent of the fish weight. The dosage of sulfamerazine was 20 milligrams per 100 grams of trout per day. It was evident that in a population of trout which were fed at the usual rate, there was considerable variation in the sulfamerazine tissue level among individual fish (Table 1, Figure 1). Even after 6 or 12 days of treatment, trout were found with only traces of sulfamerazine in their tis-

TABLE 1.—Tissue concentrations of free sulfamerazine in individual fingerling brook trout (average weight 52.5 grams) treated at a rate of 20 milligrams of sulfamerazine per 100 grams of fish per day—expressed in milligrams percent.

Days from start of treatment	Replicates						Average (A to F)
	A	B	C	D	E	F	
1.....	4.7	4.5	0.0	2.6	4.3	2.3	3.1
2.....	2.6	5.7	9.2	4.9	5.1	5.7	5.5
3.....	4.3	5.7	2.2	2.6	4.7	7.7	4.5
4.....	1.8	4.9	5.7	1.8	5.5	3.6	3.9
5.....	7.7	4.2	5.4	6.1	5.9	7.4	6.1
6.....	2.1	6.2	6.0	2.1	0.2	7.2	4.0
7.....	7.9	7.9	6.3	6.1	5.9	6.3	6.7
8.....	10.0	6.5	6.5	7.8	10.8	8.2	8.3
10.....	6.1	8.4	8.7	9.4	4.5	5.5	7.1
12 ¹	5.9	7.7	7.4	7.7	0.2	6.0	5.8
14.....	1.4	7.2	7.2	6.1	4.9	4.1	5.2
15.....	2.3	2.4	1.6	2.0	0.5	3.8	2.1
16.....	0.5	0.4	0.5	0.1	0.1	0.6	0.4

¹Treatment was stopped on the 13th day.

sues. This observation may help to explain why prolonged sulfonamide therapy sometimes fails to free all trout from *Bacterium salmonicida* in an infected population.

The wide variation in tissue levels of sulfamerazine among individual fish could be ascribed to: (a) unequal intake of food by individual fish, (b) unequal distribution of the drug in the diet, (c) individual variation in the rate of absorption or elimination of sulfonamides, or (d) any combination of the above.

In order to determine how much variation existed in the tissue concentration of trout which had been given identical doses of sulfonamide, yearling brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdnerii*), weighing on the average 55, 65, and 53 grams per fish respectively, were given sulfamerazine in single doses at a rate of 10 milligrams per 100 grams of trout per day. The drug was carefully weighed, distributed in gelatin capsules, and introduced into the stomach of fish. Tissue concentrations of free sulfamerazine were determined for different individual trout for several days following the administration of the drug and results (Table 2) indicate that there was a wide variation. The fish did not receive food during

the experiment. It is interesting to note that the rate of absorption was somewhat lower and slower with brook trout and the rate of elimination was fastest with brown trout.

QUANTITY OF MEDICATED FOOD AND THE TISSUE CONCENTRATION OF SULFAMERAZINE

Snieszko and Friddle (1951) noted that the tissue concentrations of sulfamerazine given at the same dosage were higher in older fish which were fed at a lower rate. This problem was studied further because it had practical significance.

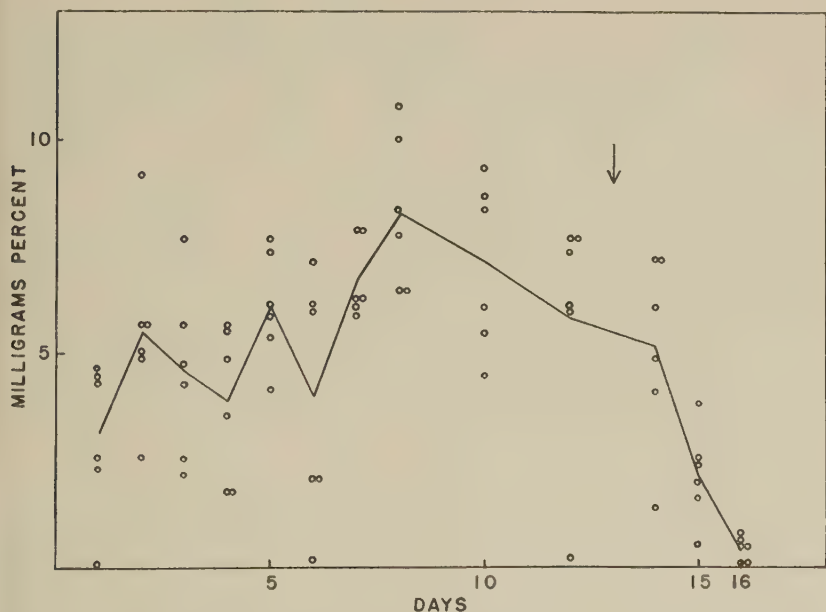


FIGURE 1.—Tissue concentrations of free sulfamerazine in individual fingerling brook trout (average weight 52.5 grams) treated at a rate of 20 milligrams of sulfamerazine per 100 grams of fish per day. Circles represent single fish, solid line the averages, and the arrow time when treatment was stopped.

Fingerling rainbow trout (average weight 27 grams) were distributed in 1.5-kilogram batches among six experimental troughs. The fish in each pair of troughs were fed at the rate of 2, 4, and 8 percent of fish weight per day. Sulfamerazine was added to all diets at a constant level of 20 milligrams per 100 grams of fish per day. All of the food was taken immediately by those fish fed at the rate of 2 and 4 percent. An excess of food remained in the troughs containing fish fed at the 8 percent level. The results presented in Table 3 and Figure

2 are very interesting because the tissue concentration increased when the quantity of food decreased. The 4 percent feeding rate described by Duell, *et al.* (1942) was about correct for fish of this size. The excessive rate of feeding resulted in a generally low tissue concentration. It appears that trout should be fed at a rate very closely adjusted to their optimum feeding requirements for the best practical results.

TABLE 2.—Tissue concentrations of sulfamerazine (milligrams percent) in trout treated with one dose of the drug introduced orally in capsules at the rate of 10 milligrams per 100 grams of fish. Determinations were made with composite samples of three trout.¹

Species	Time between treatment and examination				
	18-20 hours	2 days	3 days	4 days	5 days
Yearling brook trout.....	2.4	2.6	1.6	1.2	0.2
	2.1	2.0	1.9	2.6	0.2
	1.5	2.5	0.9	1.1	0.5
Average.....	2.0	2.4	1.5	1.6	0.3
Yearling brown trout.....	5.1	5.1	0.9	0.1	.....
	4.3	4.3	0.4	0.0	.....
	2.3	2.3	0.6	0.0	.....
Average.....	3.9	3.9	0.6	0.03	.....
Yearling rainbow trout.....	3.1	4.0	1.4	0.4	0.1
	5.5	2.3	1.4	0.6	0.1
	4.2	2.8	1.1	0.4	0.8
Average.....	4.3	3.0	1.3	0.5	0.3

¹Average weight of brook, brown and rainbow trout was 55, 65, and 53 grams respectively.

INITIAL AND MAINTENANCE DOSAGES OF SULFAMERAZINE

With humans and some domestic animals, it is an accepted practice to administer sulfonamides at a high initial dose and then to maintain a relatively high blood (tissue) concentration thereafter by administering smaller doses at frequent intervals (Northey, 1948).

To test the value of such a practice in the treatment of fish, the following experiment was carried out. Fingerling brook trout (average weight 33 grams) were distributed in 1.87-kilogram batches among six experimental troughs and fed at a 4 percent rate. The initial dosage of sulfamerazine was 30 milligrams per 100 grams of trout per day. On the 7th day of the experiment when the tissue concentration of sulfamerazine was already well leveled off, the trout were divided into three groups. Each group received sulfamerazine at a level of 30, 20, and 10 milligrams per 100 grams of fish per day. The results are presented in Table 4 and Figure 3. An initial dosage of 30 milligrams per 100 grams of trout per day produced an average tissue concentration of 9.2 milligrams percent. Lower dosage levels resulted in a correspond-

ingly decreased sulfamerazine tissue concentration. By comparing this set of data with the results obtained from another experiment (Table 3, Figure 2), it is evident that the high initial dose (30 milligrams) apparently had no greater effect on the tissue concentration than that level obtained only by treatment with the maintenance dosage of 20 milligrams per 100 grams of fish per day.

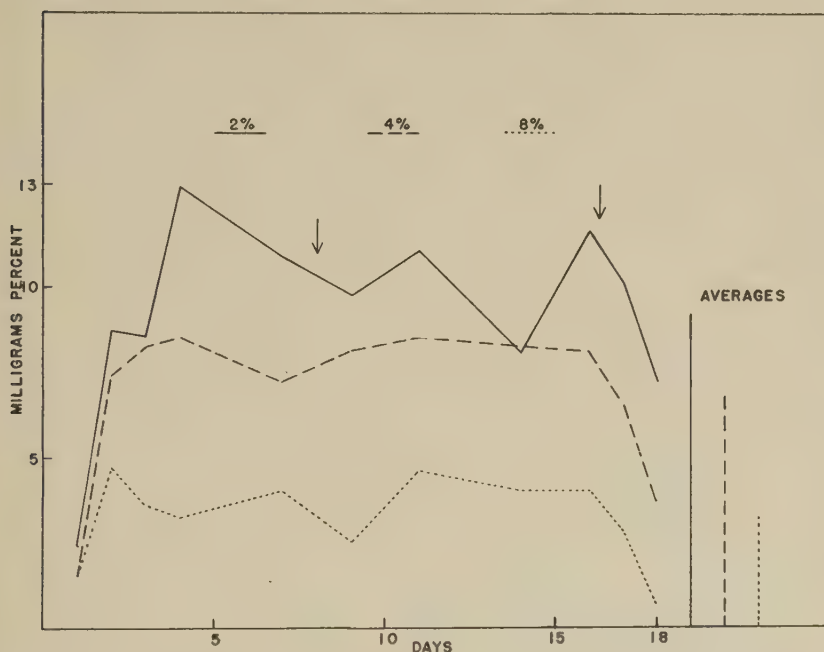


FIGURE 2.—Relationship between rate of feeding and tissue concentrations of sulfamerazine (milligrams percent) in fingerling rainbow trout (average weight 27 grams). Fish were fed at the rates of 2, 4, and 8 percent of their weight per day. Sulfamerazine was administered at a rate of 20 milligrams per 100 grams of fish per day. The left arrow indicates time of a quantitative adjustment of diets and of drug, and the right arrow end of treatment.

DISTRIBUTION OF SULFAMERAZINE IN TISSUES OF RAINBOW TROUT

Snieszko and Friddle (1951) showed the distribution of sulfamerazine in various tissues of brook and brown trout. It was believed advisable to study the distribution of sulfamerazine in the tissues of rainbow trout since this species, in contrast to the other two, responded differently to both feeding with sulfamerazine (Gutsell and Snieszko, 1949) and to treatment with pyridylmercuric acetate (Rodgers, *et al.*, 1951). Fingerling rainbow trout (average weight 40 grams) were dis-

tributed in 2-kilogram lots among three experimental troughs. They were fed at a rate of 3 percent by weight and received sulfamerazine at a level of 20 milligrams per 100 grams of fish per day. Determinations were made on composite samples of six fish, two from each trough. The results are presented in Table 5.

The blood and liver contained the highest concentration of sulfamerazine. The level was somewhat lower in the kidney and lowest in the muscle tissue. The concentration of sulfamerazine in rainbow trout

TABLE 3.—*Relationship between rate of feeding and tissue concentrations of sulfamerazine (milligrams percent) in fingerling rainbow trout (average weight 27 grams)—determinations made with duplicate samples (A and B) of three fish each.*

Days after start of treatment	Feeding rate (percentage of fish weight per day)					
	2		4		8	
	A	B	A	B	A	B
1.....	4.7	0.2	2.4	0.2	2.1	1.2
2.....	10.0	7.4	7.4	7.4	4.9	4.5
3.....	11.7	5.5	8.2	8.2	3.6	3.6
4.....	14.4	11.4	8.2	8.9	3.2	3.2
7 ¹	10.0	11.7	6.8	7.7	3.2	4.9
9.....	11.1	8.4	7.7	8.6	2.8	2.2
11.....	11.4	10.6	9.7	7.4	4.0	5.3
14.....	7.7	8.4	8.2	8.2	3.4	4.7
16 ²	12.5	10.8	7.0	9.2	3.8	4.3
17.....	10.3	10.0	7.2	5.7	2.8	2.8
18.....	6.8	7.7	4.9	2.3	0.8	0.4
Average concentration...	10.1	8.4	7.0	6.7	3.1	3.4

¹Rates of feeding and treatment were adjusted on the 8th day.

²Treatment was discontinued on the 16th day.

gradually increased during the experiment without reaching a peak level between the 8th and 10th day of treatment. This is in contrast to the results obtained in experiments involving brook and brown trout¹ (Snieszko and Friddle, 1951). It should be noticed that after each adjustment of the quantity of drug and diet, there was some increase in the drug concentrations. This could be explained on the basis of the observations noted in the present study relating to the effect of the quantity of food on the tissue levels of sulfamerazine (Table 3, Figure 2).

¹This fact by itself probably would be of little significance. However, other authors made interesting observations on some biochemical and physiological differences existing among various species of trout. For example, the growth rate of rainbow, brook, and brown trout are differently affected by sulfamerazine (Gutsell and Snieszko, 1949), pyridylmercuric acetate is toxic to rainbow trout (Rodgers, *et al.*, 1951), and requirements of biotin are different in various species of trout (Phillips, *et al.*, 1947).

RECOMMENDATIONS FOR TREATMENT

In the first paper of this series the authors discussed the importance of pharmacological investigations on the distribution of sulfonamides in trout tissues. This procedure was proposed as a rational approach to the use of sulfonamide therapy for some infectious diseases. Therefore, the present discussion will concern only those problems which are directly connected with the results presented here.

When a population of fish suffering from an epizootic is treated with sulfonamides not all of the fish receive the drug in amounts which are directly proportional to their body weight. Those which are too sick

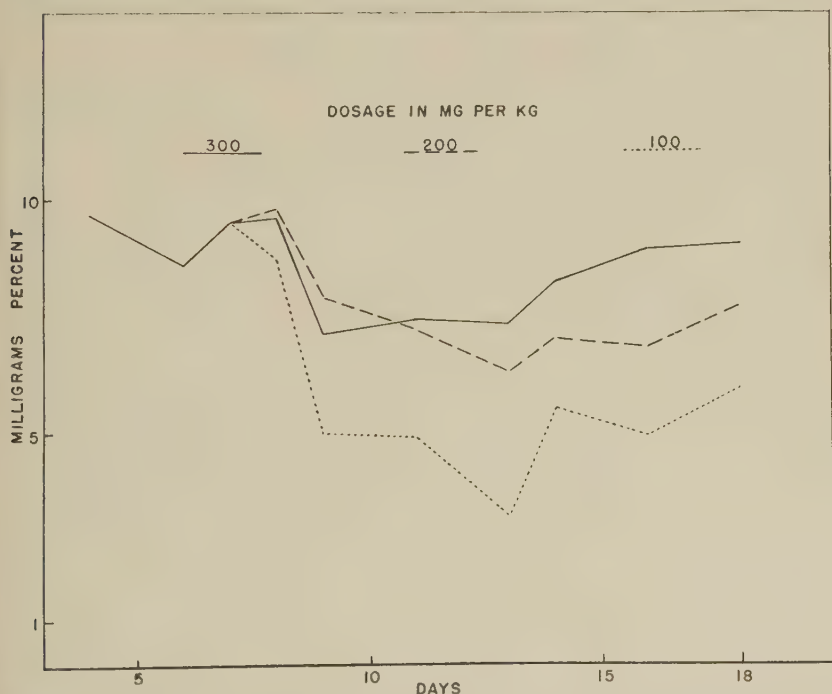


FIGURE 3.—Tissue concentrations in milligrams percent of free sulfamerazine produced by initial and maintenance dosages of this drug in normal fingerling brook trout. Dosages expressed in milligrams per kilogram of fish per day.

will not take any food, and smaller and less aggressive individuals will get less than the average amount of available feed. The data presented in Table 1 and Figure 1 show that even in a population of well graded, apparently normal, and adequately fed fish, there is great variation in the tissue concentration of sulfamerazine. Even when the drug

was introduced in carefully measured quantities into the stomach of the fish the range in the tissue concentration was much greater than could be accounted for by the experimental error (Table 2).

Another important aspect of sulfonamide therapy in fishes is the relation between the quantity of medicated diet fed and the tissue concentration of the drug (Table 3, Figure 2). The results clearly indicate that excessive feeding is wasteful and produces low tissue levels of sulfamerazine. Since the therapeutic effect of sulfonamides depends

TABLE 4—Tissue concentrations (milligrams percent) of free sulfamerazine (total sulfamerazine in parentheses) produced by initial and maintenance dosages (per 100 grams of fish per day) of this drug in normal fingerling brook trout (average weight 33 grams)—determinations made with composite samples of three trout each.

Consecutive days of treatment	Replicate troughs					
	A	B	A	B	A	B
Initial dosage (milligrams) first 7 days of treatment						
	30	30	30	30	30	30
4.....	10.3	11.2	8.7	11.1	8.9	7.9
6.....	8.2	7.4	8.4	8.4	9.2	9.8
7.....	9.2	9.2	8.2	11.4	9.4	9.4
Average 4 to 7 days.....	9.2	9.2	8.4	10.3	9.1	9.0
Maintenance dosage (milligrams) remaining 11 days of treatment						
	30	30	20	20	10	10
8.....	10.0	9.2	9.4	10.3	9.2	8.2
9.....	6.1	8.2	8.4	7.5	4.3	5.7
11.....	6.5(8.9)	8.4(9.4)	7.4(8.8)	7.1(8.2)	4.3(5.7)	5.5(6.3)
13.....	7.2	7.4	5.9	6.8	3.8	2.6
14.....	8.2(8.6)	8.2(8.6)	7.9(8.2)	6.1(6.8)	5.5(5.9)	5.5(5.9)
16.....	9.2(9.4)	8.6(9.2)	7.9(8.2)	5.7(6.3)	4.9(5.7)	4.9(5.1)
18.....	9.4(10.0)	8.6(8.4)	6.8(7.2)	8.6(8.9)	5.7(7.0)	6.1(6.1)
Average 8 to 14 days.....	8.1	8.4	7.7	7.4	5.4	5.5

on the concentration present in blood and other tissues, it follows that excessive feeding is undesirable. The low feeding rate produced high tissues concentrations of sulfamerazine, but the range of variation in the tissue concentration was also greatest. Therefore the advantage of high tissue concentration in fish fed at a low rate would be offset by the fact that all weak fish, which probably would need the drug most, would be deprived of it because of the smaller quantity of available food. Therefore for best results, the treated fish should be well graded, their total weight should be known, and the quantity of food should be correctly adjusted to the nutritional requirements of fish of this size. Feeding slightly deficient amounts of food may be preferable to excessive feeding.

The present experiments also indicate that high initial doses do not appear to have any significant effect on the tissue concentrations of sulfamerazine sustained by the maintenance doses. Within 2 or 3 days after the start of treatment, the dosage of 20 milligrams of sulfamerazine per 100 grams of fish per day (9 grams per 100 pounds) results in a tissue concentration of 7 to 8 milligrams percent and a blood level of 12 to 14 milligrams percent. These concentrations were determined to be entirely satisfactory in the treatment of furunculosis.

TABLE 5.—Sulfamerazine concentrations (milligrams percent) in various tissues of fingerling rainbow trout (average weight 40 grams) treated at a rate of 20 milligrams of the drug per 100 grams of trout per day—determinations made with composite samples of 6 fish each.

Days after start of treatment	Tissue			
	Muscle	Blood	Liver	Kidney
1.....	2.8	5.5	7.0	4.5
2.....	4.3	8.2	7.7	6.5
3.....	6.3	12.0	12.0	10.0
4.....	7.4	12.0	13.4	10.6
7 ¹	6.5	11.4	13.2	10.3
9.....	9.4	15.4	15.0	13.4
11.....	8.9	14.6	14.6 ²	13.2
14 ¹	8.4	14.3	14.0	12.4
16.....	10.0	16.4	15.4	14.6
18.....	9.4	17.3	16.0	15.0
21 ²	8.2	14.6	14.6	11.7
22.....	2.9	5.5	5.9	4.7
23.....	1.5	2.8	4.2	2.4
24.....	0.4	0.9	1.8	1.1
Average 4 to 21 days.....	8.5	14.5	14.5	12.6

¹Quantities of diet and drug were adjusted to weight of fish.

²Treatment was discontinued.

ACKNOWLEDGMENTS

The writers are greatly indebted to Dr. Philip J. Griffin who assisted in the editing of this paper, and to Mr. B. H. Hazen, superintendent of the station, for making available all trout used in these experiments.

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A STUDY OF THE LAKE TROUT, *SALVELINUS NAMAYCUSH*, IN TWO ALGONQUIN PARK, ONTARIO, LAKES

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ABSTRACT

A study was made of the depth distribution, feeding, and growth of the lake trout, *Salvelinus namaycush*, in Lake Louisa and Redrock Lake, Ontario, in 1947. In the spring the trout were widely dispersed in Redrock Lake but as surface waters warmed to 14° or 15° C. in mid-June they moved into deeper waters. During the summer months the Redrock lake trout concentrated in the lower thermocline and upper hypolimnion while those in Lake Louisa were more widespread. Both populations frequently penetrated the 15- to 20-foot zone in mid-summer up to the 18° C. isotherm. In each lake the smaller trout had a deeper distribution.

In both Redrock and Louisa the food was varied in the spring months. Insects, particularly the immature stages, were eaten extensively at this time. During the summer the Louisa trout fed on plankton as there was no other available food. The Redrock trout fed almost exclusively on the yellow perch, *Perca flavescens*, the distribution of these two species overlapping in the 12° to 18° C. zone. In both lakes a large number of empty stomachs occurred in the early fall. Small trout ate more plankton and insects and less fish than did the larger trout. Food competition and cannibalism were of little importance.

Lake Louisa trout grow more slowly than those in Redrock Lake. This difference is correlated with the difference in feeding habits. The Lake Louisa fish have a growth rate similar to other plankton-feeding populations in Algonquin Park while the Redrock trout have growth like that of piscivorous populations. The lake trout of both lakes grow slowly as compared with many growth rates reported for the species. Maturity is reached at age V in both lakes. Variation in year class strength is evident in both Redrock and Louisa lakes.

INTRODUCTION

The lake trout, *Salvelinus namaycush namaycush* (Walbaum), has been one of the least known of our commercial and game fishes. Among the factors that have contributed to this scarcity of knowledge are the trout's deep water habitat, the inability of the biologist to capture young fish, the difficulty of studying the reproduction of the species, the uncertainty of age determinations, and the great variability of the lake trout from one body of water to another. However, more attention has been paid to the species in recent years and some progress has been made towards a fuller understanding of its life history and habits.

The present study is a contribution to the knowledge of the depth distribution, feeding, and growth of the lake trout in two Algonquin

Park lakes, Louisa and Redrock. An additional aim was to determine the factors which are responsible for the differences that have been observed in the size composition, feeding habits, and size at maturity of the lake trout in anglers' catches in these two lakes.

The Lake Louisa investigation covered the periods July 7 to August 24 and October 10 to November 4, 1947. A field party was established on Redrock Lake from May 10 to July 7 and periodic return trips were made after this time until September 11, 1947. In addition some use

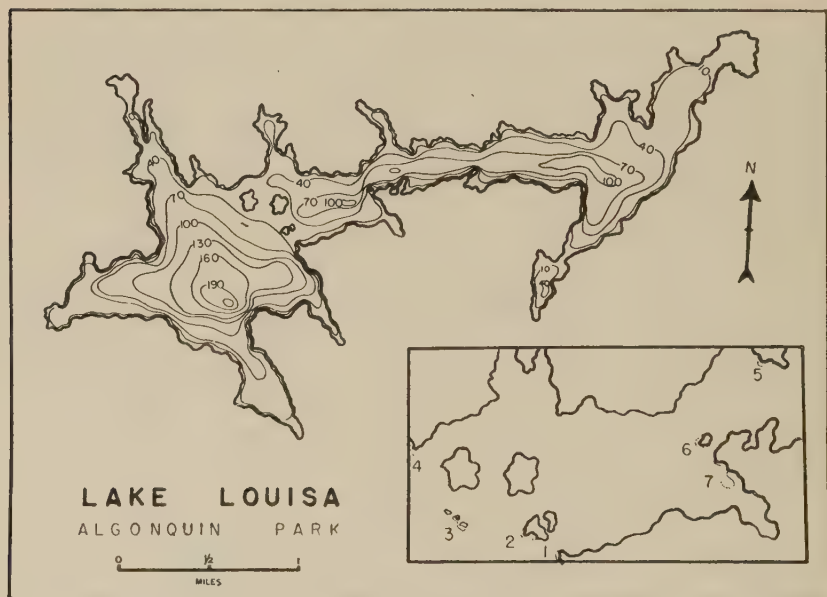


FIGURE 1.—Contour map of Lake Louisa, Ontario—contour interval, 30 feet.

has been made of material collected in the Algonquin Park creel census of preceding years, especially earlier scale collections and stomach analyses.

Algonquin Park lies on the height of land between the upper reaches of the Ottawa River and Georgian Bay. Geologically it is part of the Canadian shield. Lake Louisa and Redrock Lake are headwaters of the Madawaska and Petewawa river systems respectively, both of which enter the Ottawa River.

LAKE LOUISA

Lake Louisa (Figure 1), longitude $78^{\circ} 29' W.$, latitude $45^{\circ} 28' N.$, lies close to the southern boundary of Algonquin Park. It has a maximum length of 4.3 miles and an area of approximately 1,500 acres or about 2.3

square miles. Louisa is deeper than many Algonquin Park lakes and has a maximum depth of 220 feet and a mean depth of 65 feet. The area and percentage of different depth zones are shown in Table 1. Much of the lake basin has precipitous shores with the only extensive shallow area being located at the extreme eastern end of the lake.

A survey of bottom soil types and vegetation was made from the shoreline out to the 10-foot contour. The exposed shores are largely made up of sand and rocks. Rubble and bedrock are found in scat-

TABLE 1. — Depth zones in Lake Louisa and Redrock Lake — expressed in acres and as percentage of the total area.

Depth zone (feet)	Lake Louisa		Redrock Lake	
	Acres	Percentage	Acres	Percentage
0—15	235	15.7	325	43.6
15—30	295	19.7	65	8.7
30—45	212	14.1	150	20.0
45—60	118	7.9	115	15.4
60—75	105	7.0	91	12.2
75—100	224	14.9	.....	.....
100—150	139	9.2	.....	.....
150—220	172	11.5	.....	.....

tered patches while vegetation is almost entirely absent from these areas. Mud bottom above the 10-foot contour is restricted to the sheltered bays and vegetation is chiefly confined to the extreme ends of these bays. Temperature conditions in Lake Louisa in 1947 are shown in Figure 2. A thermocline was well established at the time the investigation was begun and weak stratification still persisted into mid-October. The various lake basins were found to have individual temperature differences but the entire lake remained well oxygenated at all depths throughout the summer months.

Eleven species of fish are known to occur in Lake Louisa. They include the lake trout, *Salvelinus namaycush*, eastern brook trout, *Salvelinus fontinalis*, white sucker, *Catostomus commersonnii*, longnose sucker, *Catostomus catostomus*, creek chub, *Semotilus atromaculatus*, lake chub, *Couesius plumbeus*, redbelly dace, *Chrosomus eos*, common shiner, *Notropis cornutus*, fathead minnow, *Pimephales promelas*, blunt-nose minnow, *Hyborhynchus notatus*, and pumpkinseed, *Lepomis gibbosus*. All of these species except the brook trout seem to be common. It is noteworthy that the perch is absent from Lake Louisa although it is almost always found in lakes of this region.

A preliminary survey of the bottom fauna of Lake Louisa was carried out by K. G. Wood. A total of 121 dredgings was taken in the first week of August and the last week of October in 1947 with a 9-inch Ekman dredge. The findings indicate that the benthos of Lake Louisa is relatively sparse (Table 2). *Chaoborus* sp., *Hexagenia* sp.,

and Chironomidae were the most important constituents of the bottom fauna. The former two were the most abundant in the first 40 feet while the latter was the predominant group in deep water.

REDROCK LAKE

Redrock Lake (Figure 3), longitude $78^{\circ} 29' W.$, latitude $45^{\circ} 46' N.$, is located approximately 20 miles northeast of Lake Louisa in central Algonquin Park. It has a maximum length of 2.3 miles and an area of 746 acres or slightly more than 1.1 square miles. This lake is much shallower than Lake Louisa and has a maximum depth of 70 feet and a mean depth of 29 feet. The slope of the basin is gradual and the

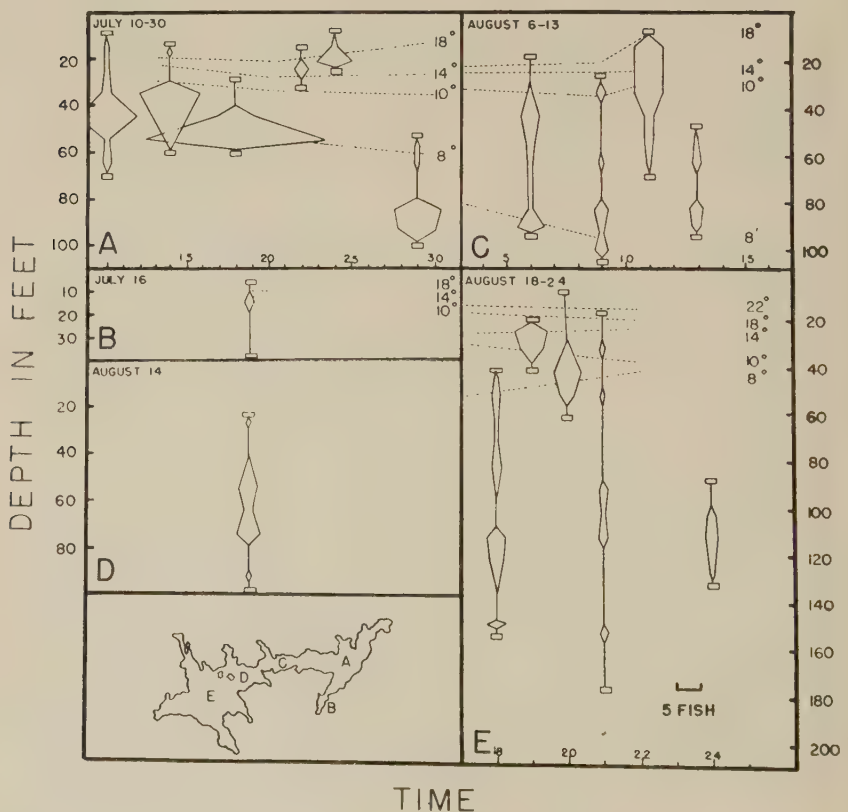


FIGURE 2.—The depth distribution of the lake trout in Lake Louisa during the summer of 1947. The distribution is shown for each of the lake basins marked on the map. Isotherms are in degrees centigrade and rectangles represent the depth range of the gill nets.

littoral zone is extensive. Figure 4 shows temperature conditions in Redrock Lake in 1947. A thermocline developed in the lake in late June and was still sharply defined at the time the investigation was terminated on September 11. Oxygen concentrations were somewhat lower than those in Lake Louisa.

Twelve species of fish are known to occur in Redrock Lake. They are lake trout, *Salvelinus namaycush*, eastern brook trout, *Salvelinus fontinalis*, round whitefish, *Prosopium cylindraceum*, white sucker, *Catostomus commersonni*, creek chub, *Semotilus atromaculatus*, lake chub, *Couesius plumbeus*, blacknose shiner, *Notropis heterolepis*, com-

TABLE 2.—The bottom faunas of Lake Louisa and Redrock Lake expressed as pounds per acre, number per acre, and percentage by weight of each general type of organism in total fauna.

Lake	Pounds per acre	Number per acre (millions)	Group of organisms				
			Chironomidae	Ephemeroptera	Chaoborus sp.	Oligochaeta	Other shallow water forms
Louisa.....	1.94	1.22	43	35	12	8	2
Redrock.....	2.73	2.70	25	25	18	11	21

mon shiner, *Notropis cornutus*, fathead minnow, *Pimephales promelas*, brown bullhead, *Ameiurus nebulosus*, yellow perch, *Perca flavescens*, and American eel, *Anguilla bostoniensis*. Redrock Lake has a good brook trout fishery and is noted for its very large perch population.

Bottom fauna surveys of Redrock Lake have been undertaken by Miller (1937) and K. G. Wood in September of 1947. The former took 60 bottom samples, the latter 32. Miller found that Redrock Lake was the most productive of the five Algonquin Park lakes he studied. Wood's findings are summarized in Table 2.

DEPTH DISTRIBUTION OF LAKE TROUT

Gill nets with meshes varying from 1½- to 4½-inch stretch measure were used to study the depth distribution of the trout. Sets were made chiefly on the bottom although floating nets were used on several occasions in Redrock Lake and suspended settings were carried on in Lake Louisa at various times. Netting was done at 18 stations in Lake Louisa but in Redrock Lake most of it was confined to two stations in the east basin. The vertical distribution of the lake trout in the two lakes is shown in Figures 2 and 4. As the Redrock samples were largely taken from the same lake basin the data are shown in one diagram. On the other hand thermal conditions differed in the various parts of Lake Louisa and the distribution is shown for each basin.

Distribution before thermal stratification.—The depth distribution of the lake trout before thermal stratification is shown only by the Redrock data as the Louisa investigation was conducted during the summer months. During early June the fish were found at all depths from 5 to 50 feet. Although the distribution was widespread, there was a concentration of fish between the 30- and 50-foot contours or the 7° and 10° C. isotherms. As the upper strata warmed during late June and the surface water reached a temperature of 14° or 15° C., there was a general downward shift of the whole population with the trout ranging from depths of 15 to 55 feet. In this downward movement

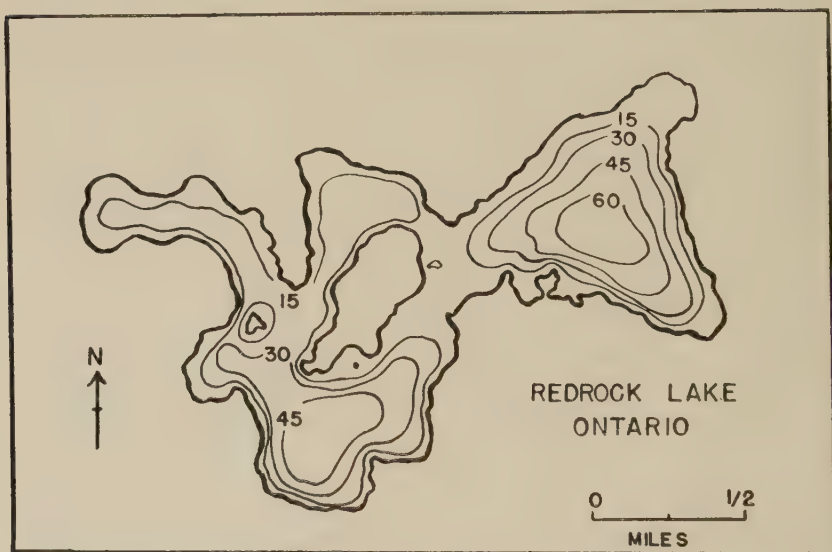


FIGURE 3.—Contour map of Redrock Lake, Ontario—contour interval 15 feet.

the upper limit of the lake trout distribution appears to be correlated with the 13° to 15° C. isotherms. Again the majority of the lake trout captured were below the 10° C. isotherm.

Distribution after the establishment of thermal stratification.—In Redrock Lake during the summer the trout are concentrated in the regions of the lower thermocline and upper hypolimnion. This concentration may be associated with the feeding habits of the fish since in this range the distribution of the lake trout and the perch, the chief summer food of the Redrock trout, overlap.

In Lake Louisa there is a more widespread distribution of trout than in Redrock Lake. Since the forage fish are largely separated from the trout in this lake by thermal conditions the latter become plankton

feeders and as such they may be more widely dispersed throughout the body of the lake. Trout which invade shallow waters are probably fish feeders. It will be noted that there is a concentration of lake trout between the 8° and 10° C. isotherms in the early samples (Basin A) similar to that noted in the Redrock population.

The most striking feature of the summer depth distribution is the presence of the lake trout in much shallower water than it is commonly believed the species will enter at this time. Fish were frequently taken in the 15- to 20-foot zone in both lakes. The upper limit of the

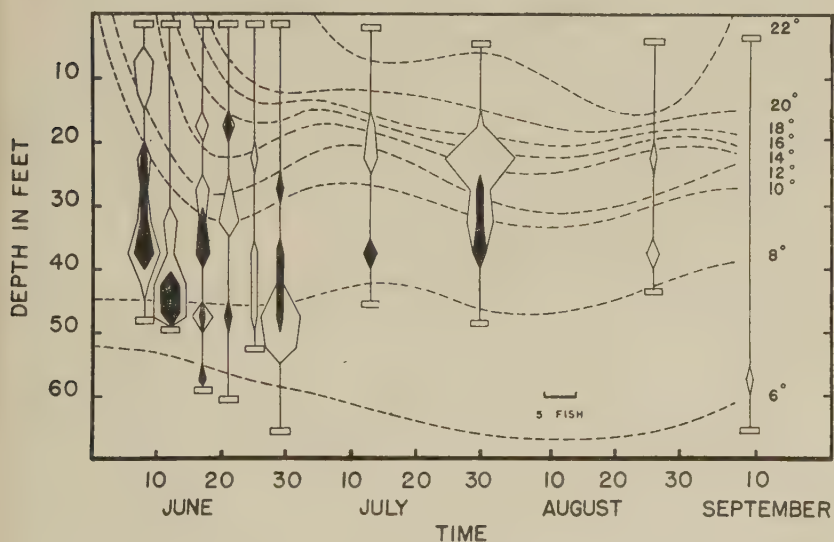


FIGURE 4.—The spring and summer depth distribution of the lake trout in Redrock Lake, 1947. Several days nettings are grouped for each vertical series of polygons. The isotherms are in degrees centigrade. Rectangles show depth range of gill nets and the solid areas represent trout less than 10 inches long.

depth distribution appears to be associated with the 18° C. isotherm. This is specifically shown by the July 29 and August 1 data for Redrock Lake and by the July 14, 22, 24 (Basin A) and August 11 (Basin C) data for Lake Louisa.

Although most of the information is based on overnight sets, it is believed that the movement of the lake trout into these shallow waters is a nocturnal habit and related to feeding. Daytime sets were largely unproductive. Similar movements have been shown for other species (Evermann and Clark, 1920; Spoor and Schloemer, 1939; Carlander and Cleary, 1949).

In Lake Louisa lake trout were captured in the deepest part of all basins. Neither temperature nor oxygen appeared to be an important influence on this distribution. Although bottom temperatures were as low as 3.9° C., they apparently did not act as a barrier to fish movement. Oxygen concentrations at the bottom ranged from 4 to 5 p.p.m. and are presumably sufficient. Oxygen rarely becomes seriously depleted in the deeper waters of Algonquin Park lake trout lakes in the summer months.

Autumn distribution.—There is no record of a return of the fish to shallow water in September. However, some observations were made during the months of October and November in Lake Louisa. In mid-October a poorly marked thermocline still persisted between 36 and 42 feet in this lake and surface temperatures ranged from 13° to 15° C. At this time the lake trout invaded shallower waters in some numbers. In an overnight set in Basin E on October 13 at depths between 4 and 70 feet, 56 percent of the catch was in the 4- to 12-foot zone and the remainder was evenly distributed at the other depths. The subsequent movements of the trout were closely related to spawning which occurred in the last part of October and the first week of November in Louisa in 1947.

Depth distribution in relation to size and age.—The relation between size and age of lake trout and depth distribution is shown in Figures 4 and 5. As there was a more complete representation of most of the size and age groups in Lake Louisa, the distribution of smaller trout is shown separately in Figure 5. It is obvious that the small trout have a generally deeper distribution than do the larger fish. In Lake Louisa the older members of the population concentrate above the 50-foot contour in the summer months while the younger and smaller are found in greater numbers below it. Generally speaking the 8° C. isotherm separates these zones. A similar situation exists in Redrock Lake. There does not seem to be any difference in the distribution of fish larger or older than the 12- to 13-inch and age V groups in Lake Louisa. During the netting operations it was observed that the small trout were often grouped in the catches. For example on July 18 in Lake Louisa a total of 18 trout, 6, 7, and 8 inches long were taken in the 53- to 58-foot range. On August 24 all the lake trout taken between 108 and 130 feet were 7 and 8 inches long. Royce (1943) has shown that yearling and 2-year-old trout in Keuka Lake concentrate on steep and rocky underwater slopes where they may seek shelter from the older members of the population. Miller and Kennedy (1948) observed that the first four summers of life of the lake trout in Great Bear Lake were spent in a boulder habitat. It is felt that a similar situation exists in the two Algonquin Park lakes.

The young trout in Lake Louisa also migrated into the shallow waters in October and November. On October 13 three lake trout 6½, 7, and 9 inches long were captured. One of these was taken in 60 feet

DEPTH IN FEET

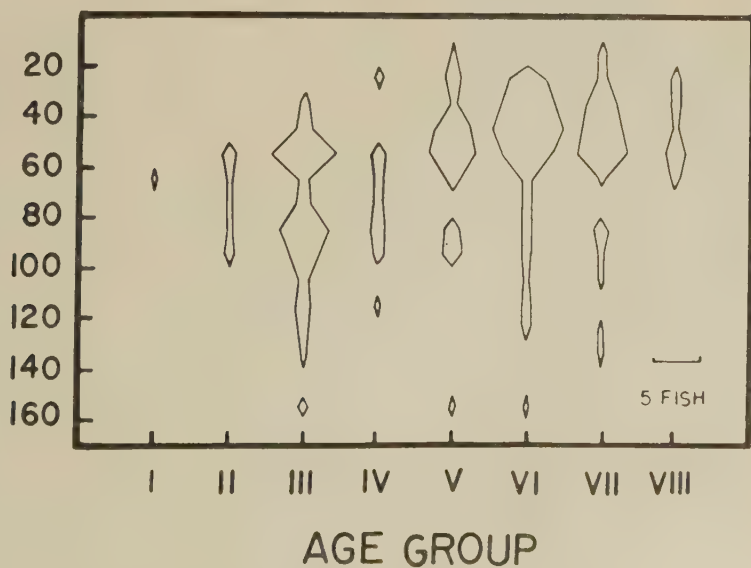
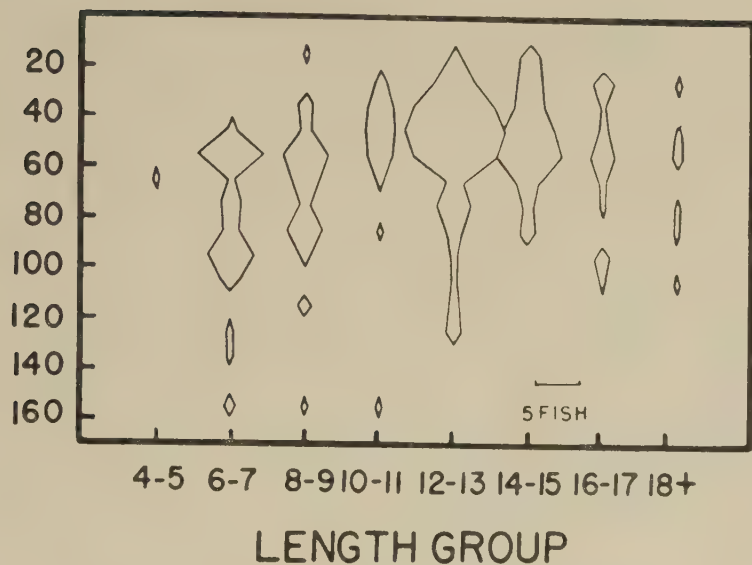


FIGURE 5.—The depth distribution of the total catch for July and August of various size and age groups of lake trout in Lake Louisa, 1947. Lengths are in inches, ages are the number of completed annuli.

TABLE 3.—Frequency of occurrence of food items in the stomach contents of lake trout in Lake Louise expressed as percentage of all stomachs containing food.

Food and Item	Period ¹										Total all fish
	May 20-31	June 1-15	July 1-15	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 16-30	Oct. 1-15	Oct. 16-31		
Total percentage containing plankton crustacea.....		100	83	85	77	67	38	41	16	73	
Total percentage containing insects.....	75	14	28	32	13	41	12		3	25	
Ephemeroptera nymphs ²											
Corixidae.....	44	50	31	23	25	4	100		100	22	
Sialidae larvae.....		100	8	23		4				12	
Chironomidae pupae.....	55			7						2	
Chironomidae larvae.....										6	
Culioidae larvae.....			62	50	13	19				3	
Tipulidae.....	22			3	88	85				49	
Bibionidae adults.....										3	
Formicidae adults.....	33		8						1	3	
Insects remains.....	11								3	1	
Total percentage containing fish.....	55	14	15	14	15	24	63	20	44	23	
<i>Salvelinus namaycush</i>											
<i>Catostomus</i> sp.....			14	9						1	
<i>Chrosomus eos</i>				18	11					5	
<i>Notropis cornutus</i>	83		14	9	11	6				3	
<i>Pimephales promelas</i>										8	
<i>Hybomachus notatus</i>				9		13		12	12	5	
<i>Lepomis gibbosus</i>				18	11	6				4	
Fish remains.....	16	100	86	55	66	81	100	100	100	75	
Total percentage containing other food.....	9		9	4	5	6		2	10	6	
<i>Gambusia</i> sp.....											
Fish eggs.....			25	100		50		100	100	35	
Freshwater sponge.....										20	
Bark, pebbles, etc.....	100		75		33	25				10	
					66	25				30	
Total stomachs with food.....	11	14	46	81	61	66	8	27	36	350	

¹No data for June 16-30 and September 1-15 periods.²Listed items are shown as percentages of each major group.

of water, the other two in less than 30 feet. On October 20 a $7\frac{3}{4}$ -inch trout was found at 40 feet, on November 2 two 7-inch trout at 11 feet, and on November 3 two 9-inch trout were taken at 20 feet. The deep distribution of small trout has been noted by other investigators. Greeley (1929) captured a lake trout $2\frac{1}{4}$ inches long in 60 feet of water in Hemlock Lake, New York. Dymond, et al. (1929) noted the capture of 11 lake trout 5 to 6 inches long in 150 feet of water, and an 8-inch specimen in 100 feet of water in Lake Ontario. Miller and Kennedy (1948), however, found Great Bear Lake trout staying in the extreme shallows until the end of their third year of life.

Most of the netting operations were confined to bottom sets but some attempt was made to fish the pelagic zone, particularly in Lake Louisa. During August two lengths of net of $1\frac{1}{2}$ - and $2\frac{1}{2}$ -inch mesh were suspended from the surface to different depths in Basin A. Only four lake trout were captured in 108 fishing hours in sets from 15 to 60 feet. Oblique sets of the type described by Fry (1937) have been used in Lake Opeongo, Ontario, by the Ontario Fisheries Research Laboratory with similar results. Cooper and Fuller (1945) used suspended sets in Moosehead Lake, Maine, and also concluded that the lake trout were largely confined to a zone just above the bottom.

STOMACH CONTENTS OF LAKE TROUT

A total of 276 lake trout stomachs were obtained from Redrock Lake and 449 from Lake Louisa. The food items were analyzed quantitatively and qualitatively as taxonomic units and then correlated with the feeding habits.

Lake Louisa.—In the Lake Louisa fish from May to October plankton crustacea occurred most frequently, being found in 62 percent of all stomachs and in 73 percent of those containing food (Table 3). Fish remains and insects each occurred only approximately one-third as frequently as plankton. By weight, however, fish was the most important item with plankton and insect remains following in that order (Table 4). Since plankton is digested more rapidly than fish, it probably made up a greater proportion of the weight than is indicated in the comparison.

There were marked seasonal differences in the occurrence and the amount of the foods taken. In the spring insects occurred most commonly but fish made up the largest part of the weight. While no plankton crustacea were found in the stomachs at this time during the summer they were predominant in both numbers and weight. As the summer progressed plankton showed a gradual decrease and at its end occurred only half as frequently as in June. During the summer fish and insects were noted occasionally but in the fall the incidence of fish increased and insects almost disappeared.

Redrock Lake.—Fish and insects were the most frequently occurring items in the stomachs of the trout of Redrock Lake during the period

TABLE 4.—Average weight of food per lake trout stomach for each 2-week period (May-October), Lake Louisa and Redrock Lake—expressed in grams.

Period	Plankton crustacea				Insects				Fish					
	Total number of stomachs weighed		Average weight of food		Number of stomachs weighed		Average weight of food		Number of stomachs weighed		Average weight of food			
	Louisa	Redrock	Louisa	Redrock	Louisa	Redrock	Louisa	Redrock	Louisa	Redrock	Louisa	Redrock		
May 1-20.....	.....	51	.....	.....	.....	44	.....	1.0	.....	.....	.....	.....	32.7	
May 21-31.....	12	33	.....	.....	10	19	.....	2.0	.....	6	.....	42	5.7	
June 1-15.....	14	39	.....	.....	3	30	.....	7.7	.....	2	.....	26	17.6	
June 16-30.....	.....	30	.....	.....	.....	27	.....	0.2	.....	.....	.....	11	2.6	
July 1-15.....	9	11	.....	.....	.....	4	.....	4.7	.....	.....	.....	11	7.9	
July 16-31.....	.....	28	.....	.....	.....	1	.....	0.1	.....	.....	.....	7	.....	
Aug. 1-15.....	14	37	.....	.....	.....	1	.....	0.1	.....	.....	.....	25	21.5	
Aug. 16-31.....	38	6	.....	.....	.....	1	.....	0.1	.....	.....	.....	7	8.5	
Sept. 1-30.....	11	9	.....	.....	.....	.....	.....	x	.....	.....	.....	6	2.0	
Sept. 1-15.....	29	.....	.....	.....	.....	.....	.....	0.2	.....	.....	.....	3	1.9	
Oct. 1-15.....	.....	.....	.....	.....	.....	.....	.....	0.2	.....	.....	.....	.....	2.7	
Oct. 16-31.....	41	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Total.....	205	214	105	4	1.1	x	17	126	1.4	6.5	55	139	2.4	17.1

x—Trace.

of study (Tables 4 and 5). Fish made up 85 percent of the total weight and insects most of the remainder. Plankton crustacea was an almost negligible item of the diet.

As in the Louisa samples, seasonal variations in the kind and quantity of the food were evident in the Redrock material. Throughout May insects and fish were found with equal frequency in the stomachs but the latter made up a much greater percentage of the weight. In June fish were taken only half as often as insects but they contributed twice the weight.

The increase in fish and the decrease in insects which was first seen in early July continued into late July and early August. By mid-August fish were found in nearly every stomach examined and insect remains were almost absent. The plankton crustacea occurred occasionally in summer but contributed very little to the total stomach contents.

Almost 80 percent of the stomachs examined in the first half of September were empty. Those which had food contained fish exclusively. During late September and October the number of stomachs containing food increased and all food items were found more frequently. Fish were particularly evident and the plankton crustacea were taken in greater numbers than at any other time.

FEEDING HABITS

Spring and early summer.—A greater variety of food in the diet of trout is evident during the spring months than at other times of the year and is caused by the increased feeding of the trout on insect forms. Insects were taken at the surface, as part of the bottom fauna, and as constituents of the plankton (Figure 6).

Surface feeding by the lake trout was entirely on insects in both lakes. It was confined to a relatively short period and would appear to be of minor importance to the species. However, an exceptionally large emergence of March flies, *Bibio* sp., in June 1947 resulted in their being taken in large numbers in Redrock Lake. Trout were observed feeding extensively on this form both in shallow water and over the deepest waters.

In both lakes bottom feeding was of much greater importance than surface feeding. Mayfly nymphs, especially *Hexagenia* sp., were the most common elements of the benthos at this time with *Sialis* sp. larvae and chironomid larvae being of less consequence. The presence of these items decreased steadily throughout the late spring and early summer months.

During the spring in both lakes trout fed to a considerable extent on plankton made up of Crustacea, *Chaoborus* sp. larvae, and the pupae of chironomids and other Diptera. Dipterous pupae were eaten in large

numbers particularly in the early part of the spring. Later the trout were gorged with *Chaoborus* sp. larvae. Fish also formed an important part of the diet in both lakes, particularly in May.

The eating of insects by lake trout has been occasionally reported in other lakes. The immature stages of mayflies, alderflies, dragonflies, phantoms, and midges have all been observed in lake trout stomachs (Fry and Kennedy, 1937; Rawson, MS. (a, b, c); Cooper and

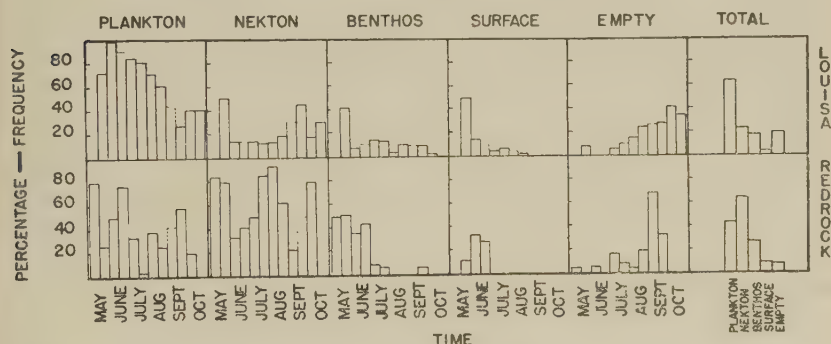


FIGURE 6.—Frequency of occurrence of various kinds of food in the stomach contents of lake trout in Lake Louisa and Redrock Lake. Data shown by 2-week periods.

Fuller, 1945; Miller and Kennedy, 1948). Records on lake trout stomachs from Algonquin Park that are on file contain numerous instances of this diet. In most cases insects are used chiefly in the spring months.

Middle and late summer.—In both lakes the summer diet of the lake trout differs markedly from that of the preceding months. Bottom and surface feeding largely cease, the food is less varied and the lake trout becomes a pelagic feeder. The kinds of food taken in the two lakes differ, however, as the Louisa trout feed largely on plankton and the Redrock fish on nekton. This difference is closely related to food availability.

A study of the vertical distribution of the forage fish populations of Lake Louisa by means of minnow traps and gill nets showed that most of the species were confined to the comparatively shallow waters. The redbelly dace and the common shiner were not found below 15 feet while the creek chub, the bluntnose minnow, the fathead minnow, and the pumpkinseed occurred slightly deeper. The lake chub and the white sucker were found down to a maximum depth of 30 feet. It is evident that all these fish live above or in the upper limits of the thermocline. With such a distribution they are largely unavailable to the

lake trout and, as has been previously pointed out, those which are eaten in the summer months are probably taken by temporary invaders into the warmer strata.

As a result of this separation the lake trout in Lake Louisa are forced to take a plankton diet. The crustacea and in particular the Cladocera were the predominant plankters found in the stomachs. Although not all stomachs containing plankton were analyzed, it was observed that a single group or form usually made up the whole contents of an individual stomach. The plankton feeding habit of the lake trout therefore does not appear to be so much a random straining of a mass as a selection of certain individuals or groups of individuals. This selection has been reported for other species of fish (Battle, et al., 1936; Ricker, 1937; Langford, 1938).

On the basis of published data plankton feeding by lake trout seems to be of rare occurrence. Hildebrande and Towers (1927) note *Daphnia* in the stomachs of Fish Lake trout. Tressler and Bere (1934) found that the lake trout of Blue Mountain Lake may feed on it to some extent. In Great Bear Lake Miller and Kennedy (1948) report a high percentage of plankton-feeding trout. However, records of observations on the lake trout in Algonquin Park lakes show that the plankton feeding habit is a common one in many of the lakes there.

In Redrock Lake the lake trout are predominantly piscivorous in the summer months, feeding almost exclusively on the yellow perch. This species is readily available to the lake trout as a source of food. Before thermal stratification they were commonly taken at all depths fished by the nets (2 to 45 feet) while in the same period the lake trout were also widely dispersed.

During thermal stratification the perch concentrate in the 18° to 20° C. range but are found in some numbers down to the 14° and 12° C. isotherms. Thus during thermal stratification there is an overlap of the depth ranges of the lake trout and the perch in the 12° to 18° C. zone which no doubt accounts for the concentration of lake trout at this level. Fry (1939) has shown that seasonal and annual variations in the amount of perch in the stomachs of Opeongo Lake trout is related to the sharpness of the thermocline.

Perch of the year first appeared in the lake trout stomachs in late July. At this time the fry had reached a length of 1½ inches and were taken in great numbers. As high as 80 percent of the trout feeding on perch in late July and early August had been eating perch hatched in the spring of that year.

In both lakes there were species of fish which lived in the same strata as the trout but which were rarely taken by it. In Louisa the longnose sucker was captured at all depths from 15 to 130 feet but rarely was found in the trout stomachs. In Redrock Lake the round whitefish has a distribution very similar to that of the trout. A large

brook trout population also occurs in this lake and has a depth distribution overlapping that of the lake trout (Baldwin, 1948). Neither of these species was eaten to any extent by the lake trout.

The lake trout fed to only a limited extent on the bottom during the summer months. Although chironomid larvae are an important constituent of the bottom fauna of Algonquin Park lakes, and the predominant deep water form in Lake Louisa, they were only occasionally eaten by the trout. Rawson (MS. a, b, c) found them in Lake Minnewanka lake trout as did Bishop (1934) in Blue Mountain Lake trout. Crayfish were occasionally noted in Louisa trout in midsummer.

Fall feeding habits and non-feeding fish.—The data on the fall feeding habits, particularly for Redrock Lake, are derived from material collected by the Algonquin Park creel census during several years and may not be comparable throughout the various periods. At this

TABLE 6.—Frequency of occurrence of food items in stomach contents of various size groups of lake trout, Lake Louisa, expressed as percentage of total sample at each time interval.

Month	Length group (inches)	Number examined	Percentage				
			Empty	Plankton	Nekton	Bottom	Surface
May.....	10—14	5	20	40	40	0	0
	15 and over	7	0	0	57	71	43
June.....	5—9	1	0	100	100	0	0
	10—14	12	0	100	8	8	17
	15 and over	1	0	100	0	0	0
July.....	5—9	30	7	93	0	30	0
	10—14	55	9	89	5	5	5
	15 and over	15	13	53	53	7	20
August.....	5—9	42	14	76	10	10	0
	10—14	79	25	62	15	5	0
	15 and over	20	25	45	25	25	15
September....	10—14	7	29	43	29	14	0
	15 and over	4	25	0	75	0	0
October.....	5—9	7	14	28	57	0	0
	10—14	85	41	45	15	3	0
	15 and over	11	36	18	54	0	0

season the lake trout fed more often on plankton than they did in the late summer months. Fish became a very important part of the diet, particularly in late fall, and little bottom feeding is evident at this time.

The most striking feature of the feeding habits is the high percentage of fish with empty stomachs in the populations of both lakes. The Louisa data, which have more continuity, suggest that there is a gradual increase in the number throughout the summer and a peak in early fall. After this peak the percentage of non-feeding trout in both lakes decreases. The reason for this period of reduced feeding activity is not known.

Temperature relations do not seem to offer a ready explanation as it would appear that the trout experience little temperature change in moving from the deep to the shallow waters at this time. The approach of spawning may be a factor although no marked difference was evident in the proportion of feeding and non-feeding fish among mature and immature trout. The number of feeding trout is at its highest in the spring and early summer months.

Size of lake trout and feeding habits.—In Lake Louisa small trout eat more plankton and less fish than do the larger, particularly in the summer when they are more widely separated from the forage fish than are the larger trout (Table 6). During the spring and fall, however, fish are a more important item in the diet of the small trout. The large trout have a more varied diet than the small fish since they eat bottom-living forms and surface organisms to a greater extent. A higher percentage of fish

TABLE 7.—Frequency of occurrence of food items in stomach contents of various size groups of lake trout, Redrock Lake, expressed as percentage of total sample at each time interval.

Month	Length group (inches)	Number examined	Percentage				
			Empty	Plankton	Nekton	Bottom	Surface
May.....	10—19	65	3	65	81	48	6
	20 and over	20	0	45	85	60	10
June.....	5—9	11	0	91	9	36	27
	10—19	53	4	62	40	43	32
	20 and over	5	0	20	40	20	60
July.....	5—9	4	0	75	0	25	0
	10—19	36	17	6	78	6	0
	20 and over	10	0	0	100	0	0
August.....	5—9	1	0	100	0	0	0
	10—19	36	3	28	86	0	0
	20 and over	4	50	0	50	0	0
September....	10—19	20	55	40	0	5	0
	20 and over	1	0	0	100	0	0

with empty stomachs is also found among the larger size groups. A similar situation exists in Redrock Lake (Table 7). Fish, other than perch, were chiefly eaten by the largest trout. The white sucker was the most common form while brook trout and round whitefish occurred infrequently.

Food competition.—Food competition between the lake trout and other species is of little consequence in either Lake Louisa or Redrock Lake. In Lake Louisa suckers and minnows may compete with the lake trout in the spring for bottom and surface forms. There is no competition for forage fish in Lake Louisa since no other piscivorous species are present there and there is probably no competition in the open water for plankton.

In Redrock Lake both the brook trout and the lake trout feed extensively on aquatic insects during the spring and early summer period. However, emphasis is placed on different and a greater variety of forms by the former species. Furthermore the relative richness of the bottom fauna may assure a sufficient supply for both. Perch are taken extensively by both species, particularly in the summer months. It is believed that the very large size of the perch population provides an adequate food supply. In addition, the ranges of the two fish only partially overlap. The burbot, *Lota lota maculosa*, one of the few piscivorous species having a habitat similar to that of the lake trout, has been generally considered as its chief food competitor (Clemens, et al., 1923, 1924; Dymond, 1928; Van Oosten and Deason, 1938). Although the burbot occurs in many Algonquin Park lakes, the species is not present in Louisa or Redrock.

Cannibalism is not important in Lake Louisa and Redrock Lake as demonstrated by the fact that out of a total of 725 stomachs examined in both lakes only one instance was noted. Two 4-inch lake trout were found in a 13-inch Lake Louisa trout. However, there are occasional references to cannibalism in other waters (Juday, 1907; Rawson, MS. b; Harper, 1948).

AGE AND GROWTH

The rates of growth of the lake trout of Lake Louisa and Redrock Lake are based on the age determinations of 347 and 195 specimens respectively. Scales were removed from the side of the fish beneath the dorsal fin and prepared for reading by impressing them on cellulose acetate slides with a jeweller's roller. Because the scales from the smallest fish captured (6 and 7 inches) could not be treated satisfactorily in this way, they were mounted in DeFauré's solution. The impressions and mounted scales were then read with a micro-projector at 60 x magnification.

Rate of growth.—It is evident that there is little difference in the growth of the lake trout of Lake Louisa and Redrock Lake up to age group V (Table 8, Figure 7), but a divergence appears thereafter. The Redrock fish continue to grow rapidly while the growth rate of the fish in Louisa declines. For example, the increase in length between age groups VI and VII in Lake Louisa is 0.9 inches while the increment in the same period in Redrock Lake is 2.0 inches. A sudden acceleration of the growth rates is apparent in the older fish of both lakes although it is particularly marked in Redrock.

These differences in growth appear to be associated with feeding habits. The young fish of both populations are plankton feeders and have similar growth patterns. However, when the Louisa trout reach a size where they might be expected to become piscivorous (12 to 14 inches) they continue to feed on plankton. The Redrock trout on the other hand have a ready supply of fish food. Perch of the year in

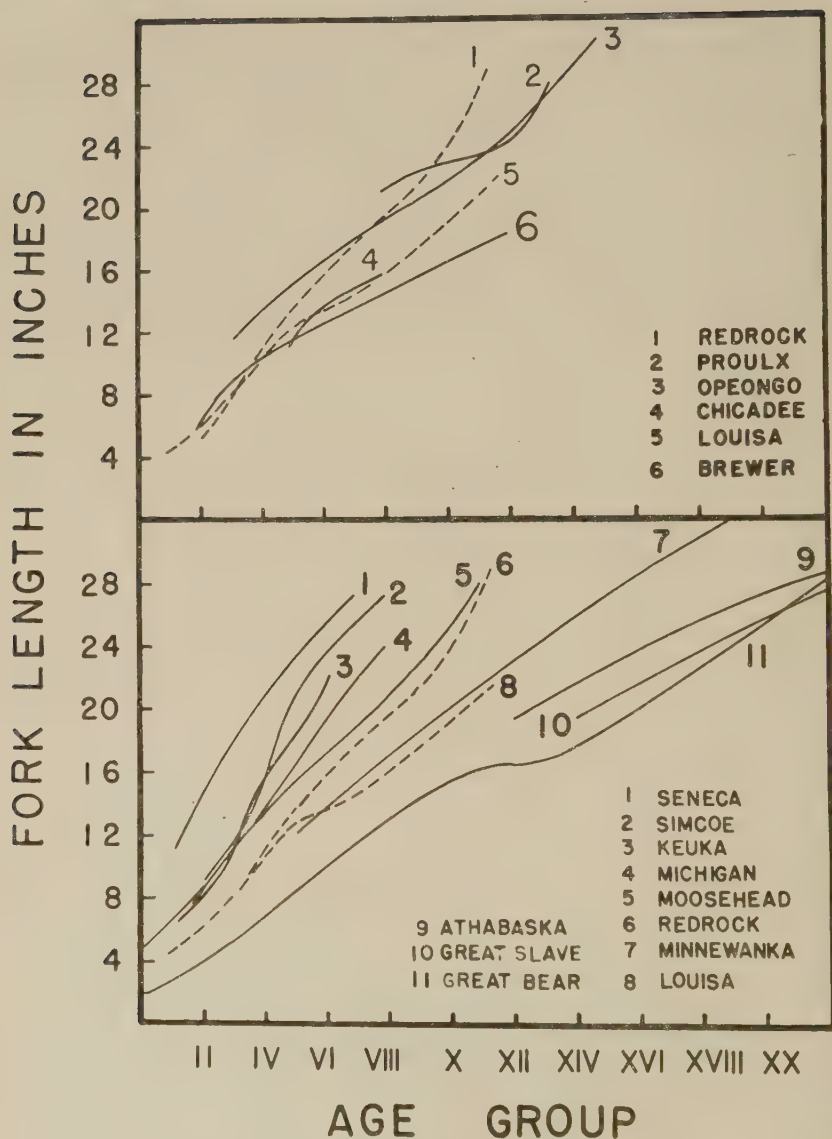


FIGURE 7.—Rate of growth of lake trout in Algonquin Park lakes (upper panel) and in lakes throughout natural range. Data from the following sources: Minnewanka (Rawson, MS.a); Seneca, Keuka, Simcoe (Royce, 1943); Michigan (Van Oosten, 1944); Moosehead (Cooper and Fuller, 1945); Athabaska and Great Slave (Rawson, 1947); Great Bear (Miller and Kennedy, 1948); Opeongo (Fry, 1949);

Age groups represent number of completed annuli.

particular should form an ideal bridge for the smaller trout transferring from plankton feeding to a piscivorous habit as would the relatively greater quantity of bottom fauna in Redrock Lake.

A comparison of the two populations with those of other Algonquin Park lakes shows that they all tend to fall into two groups. The Redrock trout have the rapid growth characteristic of the more piscivorous populations, such as those of Proulx and Opeongo lakes, while the Louisa fish group with the slower growing plankton-feeding trout of Brewer and Chicadee lakes.

The accelerated growth in the older fish may be caused by their eating larger forage fish. Such acceleration is also apparent in other Algonquin Park lakes such as Proulx and Opeongo and is most pronounced in the more strongly piscivorous populations. Plankton-feeding

TABLE 8.—*Calculated lengths of lake trout at each age in Louisa, Redrock, Proulx, Brewer, and Chicadee lakes, Algonquin Park, Ontario.*

Age group	Fork length in inches				
	Louisa	Redrock	Proulx	Brewer	Chicadee
I.....	4.1	.....	.....	.....	.....
II.....	6.9	5.8	.....	5.5	.....
III.....	7.7	7.4	.....	9.5	.....
IV.....	9.6	10.9	.....	10.7	.....
V.....	12.8	13.2	.....	11.6	11.0
VI.....	13.5	15.8	.....	12.6	14.0
VII.....	14.4	17.8	.....	14.0	15.0
VIII.....	15.8	19.4	21.0	14.0	15.3
IX.....	17.3	21.2	22.3	.....	.....
X.....	20.5	25.0	22.8	.....	.....
XI.....	20.0	28.7	23.0	.....	.....
XII.....	21.8	29.5	26.0	18.0	.....
XIII.....	.....	.....	26.5	.....	.....

trout probably do not reach a size where they can avail themselves of the larger food elements. Cooper and Fuller (1945) also found more rapid growth in the large lake trout in Moosehead Lake and attribute it to their eating large suckers.

The growth rates illustrated in the lower panel of Figure 7 are based on the publications of various authors and the curves are drawn from the writer's interpretation of their tabulated data. They are primarily employed to show the general differences in the growth of the trout of various localities rather than the detailed description of any one population.

There is a wide diversity of growth rates throughout the geographic range of the species. The lowest curves represent the growth of trout in lakes in the northern limits of its distribution in northwestern Canada, those in the upper part the growth of populations bordering on the southern limits of its range in New York State. The curves reveal an interesting progression of growth from north to south. Fish in the fifth

year of life, for example, may range from 7 inches in Great Bear Lake to 21 inches in Seneca Lake. The growth curves of the two Algonquin Park populations tend to fall in the lower series, which are relatively slow growing fish.

There appears to be no difference in the growth of the sexes in Redrock Lake. In Lake Louisa, on the other hand, the females grow faster than the males up to age group VI. At this time the rates of growth become similar. Various authors have presented evidence for and against differential growth of the sexes in lake trout. Royce (1943) believes the females grow slightly faster than the males in Seneca Lake and Lake Simcoe while Miller and Kennedy (1948) and Fry (1949) find no significant differences in Great Bear Lake and Lake Opeongo respectively.

Age at maturity.—No lake trout mature before their sixth year of life in either Redrock Lake or Lake Louisa. In their sixth year a high percentage of fish of both sexes mature in Lake Louisa while only a few males and no females reach maturity in Redrock Lake. These data show general agreement with the findings of other investigators.

Year class composition.—Strength of year classes in Algonquin Park lakes is extremely variable (Fry and Chapman, 1948) and fluctuations are particularly marked in Lake Louisa. The age composition of the lake trout populations of Lake Louisa and Redrock Lake, based

TABLE 9.—*Age composition of lake trout captured in gill nets, Lake Louisa and Redrock Lake, 1947.*

Age group	Year class	Percent of total	
		Louisa	Redrock
I.....	1946	0.4	0.0
II.....	1945	3.9	6.9
III.....	1944	20.9	4.6
IV.....	1943	7.0	26.4
V.....	1942	14.2	20.7
VI.....	1941	29.2	10.4
VII.....	1940	16.6	14.9
VIII.....	1939	5.0	6.9
IX.....	1938	1.7	5.7
X.....	1937	0.4	0.0
XI.....	1936	0.4	0.0
XII.....	1935	0.4	1.1
XIII.....	1934	0.0	1.1
XIV.....	1933	0.0	0.0
XV.....	1932	0.0	1.1

on gill net catches, is shown in Table 9. The use of gill nets to determine the relative strength of year classes has limitations since mesh selectivity or non-random distribution of net sites may affect the results. In the present investigation netting was carried on over a wide enough range of situations and with enough variation in mesh size to permit general observations. The data for Lake Louisa are better because the size range of the population is small.

The 1945 and 1946 year classes in Lake Louisa and the 1944 and 1945 in Redrock Lake are probably inadequately represented as the 1½-inch mesh, the smallest in operation, failed to capture many. In Lake Louisa the strongest year class was that of 1941. Over 40 percent of the fish large enough to be caught by anglers are in this year class. No dominant year classes occur before that of 1941 and there appears to be an orderly decrease in the relative abundance of preceding year classes due to the effects of fishing effort and natural mortality. The most striking feature of the age composition of the Louisa population is the presence of a strong 1944 year class. One fish in five of those captured was in its fourth year of life. The 1943 year class appeared to be weak.

In Redrock Lake the data are less complete. However it appears that there are two strong year classes in the years 1943 and 1942. Between them they made up about half of the total catch.

DISCUSSION AND CONCLUSIONS

Generally speaking the depth distribution of the lake trout in these lakes follows the commonly accepted pattern; shallow water in the spring, deep water in the summer, and shallow water again in the fall. This behavior has been observed in numerous lakes and has been generally related to temperature conditions. However, it is evident from the present study that this characteristic pattern may be subject to some modification. In Redrock Lake the lake trout were not confined to the shallow waters in the spring months but were rather widespread. As a matter of fact there were as many fish below the 30-foot contour as above it at this time. In both lakes the lake trout were not continuous inhabitants of the profundal depths in the summer months but considerable numbers frequented warmer and shallower waters at least in the night hours. In general there were more fish above the 50-foot contour than below it in Lake Louisa, and in Redrock Lake the center of population density was shallower in the summer than in the spring.

It is evident from the study of these two lakes that the lake trout is highly omnivorous and has marked seasonal changes in its diet. The fish may be almost exclusively plankton feeders, bottom feeders, fish feeders, or non-feeders at different times. Although such variations have been observed occasionally in other lakes, they have usually not been so marked. It is apparent that food studies made in lakes at one particular time of the year are not necessarily indicative of the food habits generally. The almost complete reliance of the lake trout on a plankton diet for 5 months of the year, as is the case in Lake Louisa, is a food habit not usually associated with this species.

Growth of lake trout varies greatly in lakes throughout its range and also in lakes of the same general area. The variations of growth rates throughout the range may, generally speaking, be related to changes

in latitude and the factors that vary with it. The differences observed in the same general latitude, such as in the Algonquin Park lakes, results from variations in local conditions.

In the present study depth distribution, food, and growth of the lake trout were shown to be closely inter-related. The difference in the growth rates between the two lakes appears to be associated, in part at least, with the relative depth distribution of the trout and their food. Forage fish are available to the Redrock trout and unavailable to the Louisa fish for a considerable part of the year. Because fish flesh would afford a much more substantial diet per unit of effort than plankton it is reasonable to expect better growth in Redrock Lake. The amount of food present in the two lakes may also be a factor in growth. Louisa, with a precipitous basin and no productive shallow areas, has a proportionately sparser bottom fauna than does Redrock. This assumption is borne out by the fact that bottom-living forms were found much more frequently in the lake trout stomachs from the latter lake.

Temperature is not believed to be a primary factor in determining growth rate although it has a secondary role as it creates a thermal barrier that separates the Louisa trout from the forage fish and necessitates their feeding on plankton.

This difference in growth offers a logical explanation for the observed variations in the size composition and size at maturity of the trout in anglers' catches in these two lakes. In Lake Louisa the average length of the anglers' catch over the last 12 years has been 14 to 15 inches and few fish are taken over 16 inches in length. The trout were found to mature in large numbers at about 12 inches. In Redrock Lake the average length of the anglers' catch has been 17 to 19 inches and fish are frequently taken up to 25 or 30 inches. The majority of the Redrock trout do not mature until they are about 16 inches in length.

As was pointed out in the discussion of lake trout growth, variations such as these have been widely observed in other Park lakes through the Algonquin Park creel census. The two lakes studied are typical of two contrasting groups, the slow growing plankton feeders and the faster growing fish feeders. Probably intergrades exist between these two extremes. The variation in size at maturity which results from these growth differences has important implications in fishery management. Although such a discussion is largely beyond the range of this paper two points may be made. First it is quite obvious that such a diversity would make it impossible to institute legislation designed to protect immature stock even in such a comparatively small area as Algonquin Park. Size at maturity may range anywhere from 10 to 19 inches in the various lakes. Secondly it may be noted that in lakes such as Louisa where the fish mature at a small size, an appreciable part of the mature population is untouched by the angling

methods now in use. It is obvious then that spawning escapement must be high in this lake. In Redrock Lake, on the other hand, considerable angling pressure is placed on the trout before they have spawned for the first time. This latter condition doubtless has important effects on the quality of the fishing in these and other Algonquin Park lakes.

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THE OPERCULAR BONE AS AN INDICATOR OF AGE AND GROWTH OF THE CARP, *CYPRINUS* *CARPIO* LINNAEUS¹

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As part of an investigation of the non-game fish resources of Utah, a study of the age and growth rate of the carp was instituted. A preliminary investigation indicated that the opercular method was superior to several other methods of determining age and growth. Age and growth were calculated from the opercular bones of 330 carp collected at Ogden Bay Refuge in 1950-51. Distances to annuli were measured directly. The relationship between the posterior radius of the opercular bone and the standard length of the carp was curvilinear. Past growth was calculated with a logarithmic nomograph. Expected number of annuli on opercular bones of known age carp, agreement of ages assessed by length frequency modes and those assessed from opercular bones of the same fish, agreement of ages assessed by empirical length frequency modes with modes formed by pooled calculated lengths, agreement between ages assessed by scales and opercular bones, and increase in age with increase in size were accepted as evidence of the validity of the opercular method. Decrease in growth rate at any year of life for successive age groups is attributed to a gradual change of the environment.

INTRODUCTION

An investigation of the non-game fish resources of Utah by the Wildlife Management Department of Utah State Agricultural College was begun in 1948 to determine the ecological and economic status of the large numbers of non-game fish known to exist in the valley waters. The creation of many artificial impoundments has greatly augmented the habitat of the non-game species, especially the carp *Cyprinus carpio* Linnaeus. Sigler (1949) estimates that there are at least one million acres of potential carp range in Utah. Study of the growth rate of the carp was initiated as part of the investigation of the non-game fish resources. Although the first conclusive evidence for the validity of the scale method was obtained from a study of carp scales by Hoffbauer (1898), the scales of this species from several habitats in northern Utah were unsuitable for determination of age and growth. It was therefore decided to use one of the several bony structures which have been used successfully to determine age in fish (Menon, 1950). The opercular bone as used by Le Cren (1947) seemed to be the most suitable for the present study so it was selected for the age and growth calculations.

¹Presented in partial fulfillment of the requirements for the degree of Master of Science in Fishery Management.

Ogden Bay Bird Refuge, the source of the carp used in the study, is essentially a shallow water, marshy habitat. The one feature of this area that has the most influence on the growth calculations is the constant eutrophication of the habitat since its construction in 1938. The originally barren salt flat has now become a heavily vegetated marsh. This change is mostly due to the deposition of large amounts of silt and municipal sewage by the Weber and Ogden rivers which are impounded here.

METHOD OF ANALYSIS

The relationship of the opercular bone to the standard length was established from measurements on 401 carp. The opercular bones from 330 carp were used in the age and growth determinations. The carp from Ogden Bay Refuge were collected with seines. Small fish for length-frequency estimates were taken with a 10-foot minnow seine, and large fish for age and growth determinations were collected with a 100-foot seine having three-quarter inch, bar measure, mesh. The wide range of sizes taken in the 100-foot seine indicates that the gear used was not excessively selective.

The standard, fork, and total lengths were taken to the nearest millimeter on a conventional measuring board. Length conversion factors are as follows: standard length in millimeters to total length in millimeters, 1.2512; standard length in millimeters to total length in inches, 0.04934; and standard length in millimeters to fork length in millimeters, 1.0862.

The scales from the area between the end of the pectoral fin and the beginning of the dorsal fin, and lying immediately above the lateral line, were taken from either side of each fish. Carp having well developed gonads, but judged not to be ready to spawn for the first time until the following season, were classified as sub-adult. The majority of the carp classified as sub-adult could be sexed macroscopically. Carp with small and sexually undifferentiated gonads were classed as juveniles and their sex was not determined.

The entire opercular assembly was removed from each carp. The first step in the removal was the severing of the skin which comprises the dorsal attachment of the opercular assembly. The branchiostegal rays at the ventral border of the opercular assembly were cut next leaving the opercular assembly attached at the anterior border. The opercular assembly was then bent sharply forward to disarticulate it from the cranium. With the opercular assembly still held forward, a knife blade inserted along the anterior border severed the skin connection and completed the removal.

The opercular assemblies were frozen if they were not to be cleaned immediately to prevent drying or decomposition. The unwanted parts of the assembly were removed by placing the entire complex in boiling water for about 1 minute and then pulling them away from the

opercular bones with the fingers. Persistent pieces of skin were removed by scrubbing with a stiff bristled brush. When the opercular bones were clean, they were set aside until dry enough to store.

The measurement of growth to each annulus was made from the posterior margin of the fulcrum to the posterior-most point of the annulus (Figure 1). Cross-sections through the fulcrum indicate that the posterior margin of the fulcrum is directly over the origin of growth of the posterior field of the opercular bone. Le Cren (1947) arrived at the same conclusion for opercular bones of perch. The dis-

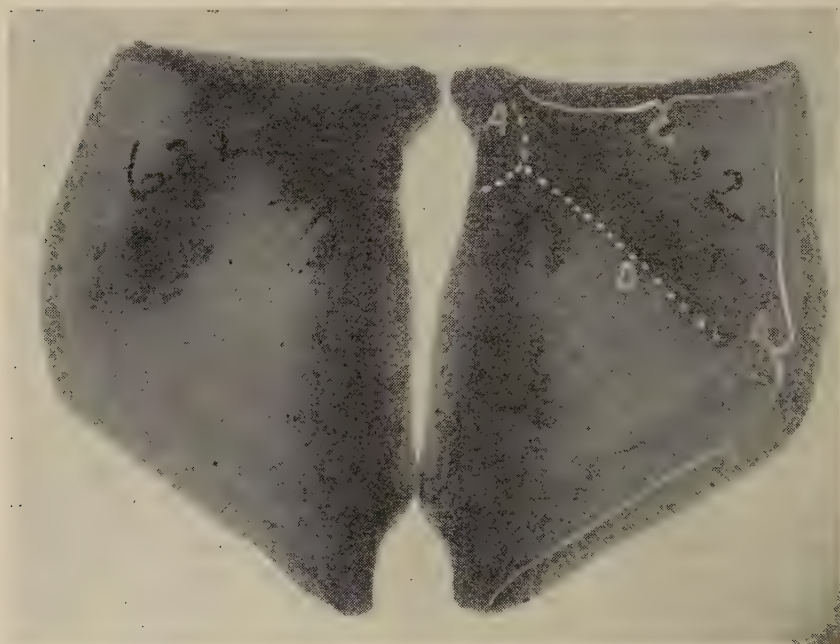


FIGURE 1.—Opercular bones of a 4-year-old female carp with a standard length of 567 millimeters, collected at Ogden Bay Refuge July 9, 1950. The posterior rim of the fulcrum (A) is outlined on the right opercular bone. (B) is the posterior margin of the opercular bone, (C) the dorsal margin, and (D) the line along which measurements were made. The line D bisects the posterior-most point of each annulus.

tances from the fulcrum to the annuli were measured directly with a draftsman's compass-pen employed as a pair of dividers. The nibs of the pen were easier to place on the posterior margin of the fulcrum than the single point of conventional dividers or calipers.

Distances set off with the compass-pen were transferred to a millimeter scale constructed with an upturn at the zero end on which the nibs of the compass-pen were placed when distances were measured.

The position of the compass-pen on this scale approximated the position of the compass-pen when the nibs were placed on the posterior rim of the fulcrum of larger opercular bones. The upturn on the scale assured that the nibs of the pen were elevated above the scale a distance equal to that between the posterior rim of the fulcrum and the origin of growth of the posterior field which lies directly beneath the posterior rim of the fulcrum. To construct the ruler, a plastic millimeter scale was cemented to a strip of aluminum sheeting 5 inches by 1 inch and 0.030 inches in thickness. A right-angle bend was made at one end of the aluminum strip and trimmed so that it extended 7 millimeters above the upper surface of the aluminum strip. The plastic scale was cemented to this strip with the zero end against the right-angle bend. A 7-millimeter bend was found satisfactory for all opercular bones with radii exceeding 25 millimeters. For all opercular bones with radii less than 25 millimeters a flat scale was satisfactory. Measurements made in this fashion were recorded to the nearest half millimeter.

DETERMINATION OF AGE

The annuli are distinct, narrow bands parallel to the posterior margin of the opercular bone. Each annulus also extends along the dorsal and anterior margins but the bone in these areas is too thick and opaque to permit easy observation (Figure 1). The area enclosed by each annulus is of the same shape as the opercular bone. This condition suggests that the annulus was the margin of the opercular bone at some earlier time in the life of the carp. Each annulus is composed of two parts. Posteriorly it is a thin line that is darker than the surrounding area, and anteriorly it is a slightly wider band which is noticeably more translucent than the rest of the opercular bone. The annuli of the opercular bones of carp are essentially the same as those on the perch opercular bones described by Le Cren (1947).

Transmitted skylight was best for observing the annuli. Light from a tungsten lamp was usable but was too highly diffused. Le Cren (1947) used polarized light to aid in distinguishing the annuli of opercular bones of perch. The annuli on the opercular bones of carp viewed by polarized light were no more easily seen than when viewed by skylight. Photography, with infra-red sensitized film, exposed through a wratten No. 87 filter, failed to give any more differentiation of the annuli than photography with ordinary panchromatic film.

The majority of the opercular bones could be aged with little difficulty. The last two or three annuli were often crowded in fish over 5 years of age. This crowding did not offer serious difficulty to age evaluation. By tracing each annulus from the dorsal margin of the opercular bone to the anterior margin where it disappeared, it was possible to determine the limits of most of the crowded annuli. False annuli were evident on many of the opercular bones, but were usually

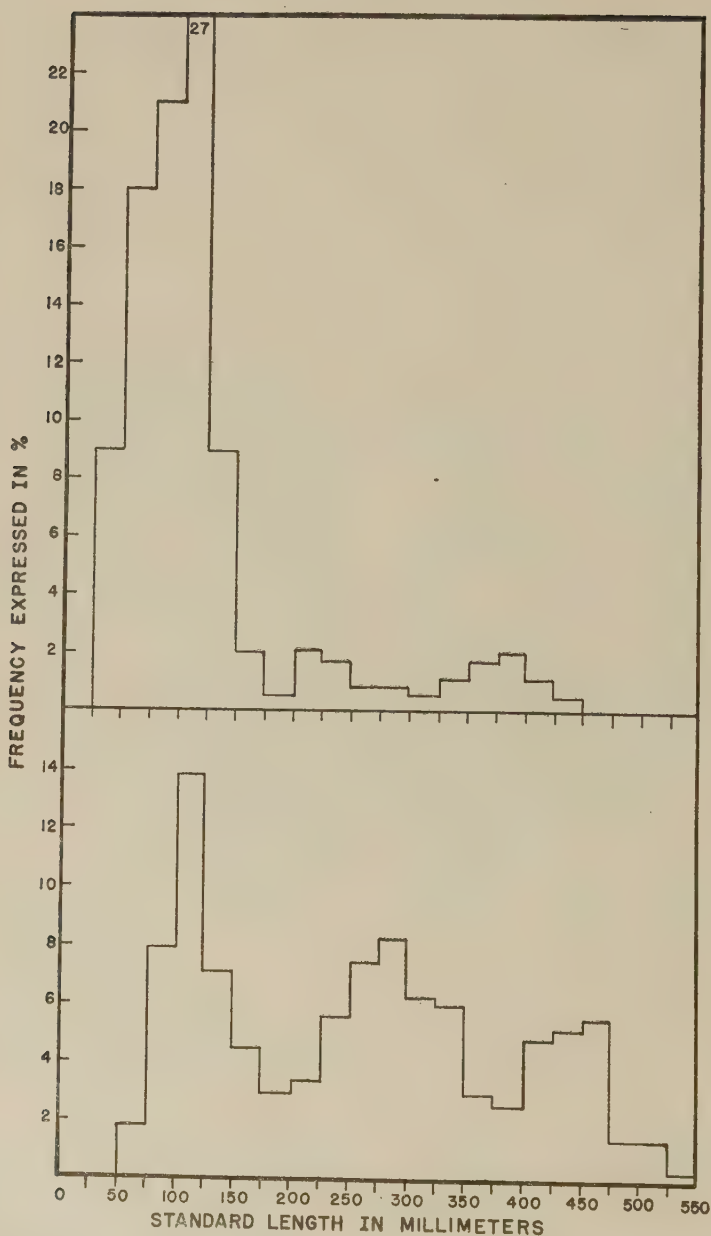


FIGURE 2.—(Upper) Frequency of empirical lengths of carp collected in December 1950 and March 1951 at Ogden Bay Refuge. (Lower) Frequency of pooled calculated lengths of carp in age classes I, II, and III, collected at Ogden Bay Refuge during 1950 and 1951.

incomplete, appearing only in a sector of the posterior field. The false annuli were fainter and did not exhibit the distinct dark and translucent zones evident in the true annuli.

The annulus laid down during the first winter of life could not be located accurately on about half of the samples. The first annulus was not a sharp, definite line in many of the fish 3 years of age and younger. The change from the end of the first year's growth to the beginning of the second year's growth appeared as a wide band containing many small accessory marks. This difficulty in locating the first annulus was further complicated on large opercular bones by buttresses radiating posteriorly from the fulcrum. The buttresses often covered the area where the first year mark would normally appear. Le Cren (1947) experienced similar difficulty on the opercular bones of the yellow perch.

The important problem was to determine whether the first visible annulus was deposited at the end of the first or the second year of life. Examination of the modes of length frequency, for both calculated and empirical lengths, indicates that there are few fish in the 176-200 millimeter length group (Figure 2). Accordingly it was assumed that few 1-year-old carp were longer than 176 millimeters and few 2-year-old carp were smaller than 200 millimeters. The latter assumptions were borne out by examination of the opercular bones from rapidly growing carp known to be 2 years old. These known-age carp were all above 275 millimeters in standard length when captured at the end of the second year of growth. Growths calculated from the first annulus on opercular bones of the known age carp were all less than 176 millimeters. From the foregoing observations it was decided that annuli, from which a standard length longer than 200 millimeters could be calculated, were probably formed at the end of the second year of growth, and annuli, from which a standard length of less than 200 millimeters could be calculated, were probably formed at the end of the first year of growth. An arbitrary division based on the foregoing evidence was employed to determine whether the first visible annulus was the first or second one deposited. Some degree of inaccuracy was probably introduced by rapidly growing 1-year-old fish, and very slowly growing 2-year-old fish. It is believed, however, that the error is small since only 20 percent of the calculated lengths for the first and second years of life are between the wide limits of 176 millimeters and 225 millimeters.

CALCULATION OF PAST GROWTH

When past growth of fish is calculated from year marks observed on bony structures, it must be demonstrated that a definite relationship exists between the size of the structure and the length of the fish. The

relationship between the posterior radius of the opercular bone and the standard length of the carp from Ogden Bay Refuge, is represented by the formula:

$$L = K \times R^n,$$

where L is the standard length, K is a constant, R is the radius of the opercular bone, and n is a constant exponent (Figure 3). Le Cren³ (1947) demonstrated that the relationship between the length of the body and the length of the opercular bone of the yellow perch was best represented by this same type formula. By application of the method of averages the following numerical values for the constants were found:

$$L = 6.854 \times R^{1.139}$$

The actual calculations of growth were made by using a logarithmic nomograph essentially the same as the one described by Hile (1950).

VALIDITY OF AGE AND GROWTH DETERMINATION

In an effort to determine the degree of correlation existing between ages assessed by the opercular method and those assessed by the scale method, scales from all carp in the study were examined. Only 20 percent of the scales examined could be aged with confidence. Some of the difficulties encountered were: cloudy centers which often obscured the first two annuli, many false annuli that were difficult to differentiate from the true annuli, and crowded annuli past the fourth year that could not be distinguished. Moen³ concluded that the scales from Utah carp were very difficult to age after examining a large sample. This may be a peculiarity of the carp of Utah as Schoffman (1942) and Eddy and Carlander (1942) reported no difficulty in aging carp by the scale method.

Sixty-six percent of the scales from the carp of Ogden Bay Refuge that could be read gave the same age as the corresponding opercular bones. Twenty-five percent of these scales indicated ages that were within 1 year of those determined from the corresponding opercular bones. Only 9 percent of the scales disagreed by 2 years or more. Of the scales that did not indicate the same ages as the corresponding opercular bones, 73 percent indicated lower ages. Attempts to discover the source of this discrepancy indicated that the annuli which could be seen clearly on the margin of the opercular bones of some of the older carp, were indistinguishable on the scales. When scales and opercular bones from the same carp were examined side by side practically all differences in age assessment could be reconciled. The fact that 66 percent of the scales read indicated the same age as the corresponding opercular bones and 91 percent agreed within 1 year was accepted as evidence that the same growth phenomenon was responsible for annuli on both.

³Personal communication.

The right and left opercular bones from a carp consistently indicated the same age. Furthermore, past growth calculated from a right opercular bone agreed closely with past growth calculated from the corresponding left one. A high degree of symmetry was exhibited between all right and left opercular bones, even to the production of identical deformities (Figure 1).

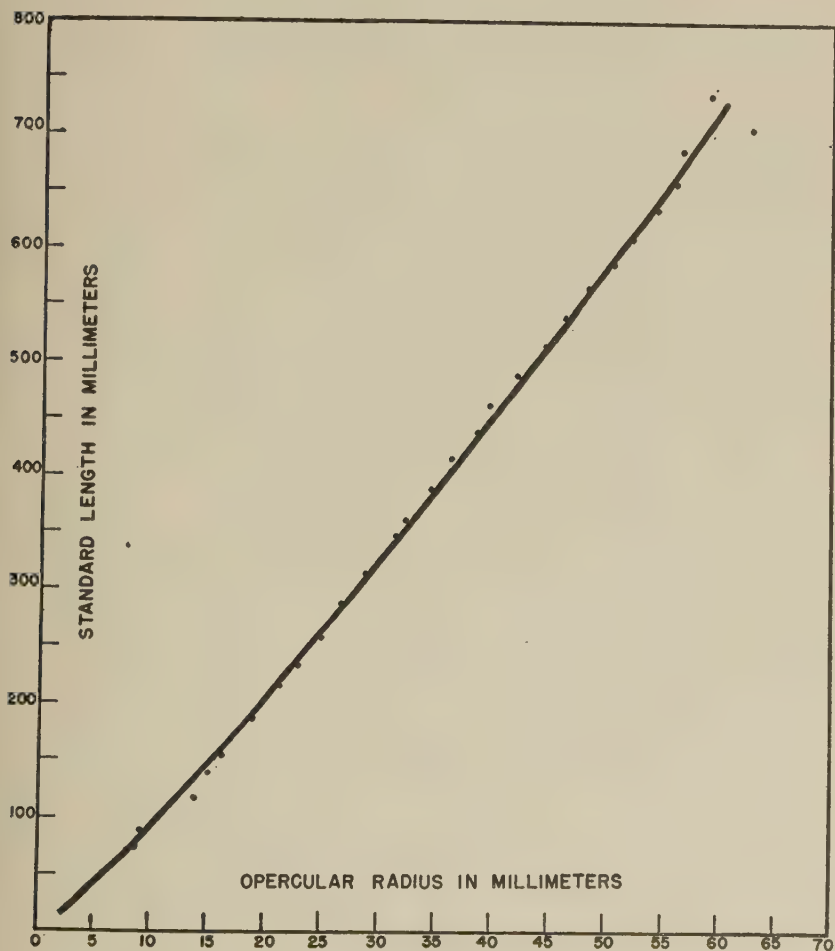


FIGURE 3. — Opercular bone-body length relationship established from measurements of 401 carp collected at Ogden Bay Refuge during 1950 and 1951. The formula for the best fit line is $L = 6.854 \times R^{1.139}$. Dots are based on average standard length and average posterior opercular radius for 25-millimeter length groups.

TABLE 1.—Summary of the mean standard lengths and annual length increments in millimeters calculated from the opercular bones of carp collected at Ogden Bay Refuge in 1950 and 1951.

Age group	Number of fish	Standard length at capture	Calculated length at end of year of life							
			1	2	3	4	5	6	7	8
I.....	33	231	114	268	427	520	561	580	582	575
II.....	37	377	116	287	423	509	540	551	551	577
III.....	69	494	129	287	423	489	519	541	577	575
IV.....	64	574	144	283	413	489	540	552	577	575
V.....	81	605	154	277	390	462	485	541	577	575
VI.....	33	614	153	260	367	422	485	541	577	575
VII.....	11	614	171	232	330	422	485	541	577	575
VIII.....	2	609	.....	.....	.....	.....	.....	.....	.....	.....
Grand averages and total.....	330	.....	138	281	414	506	551	572	577	575
Increments of growth.....	.....	.....	138	131	131	97	53	39	27	-2
Equivalent total lengths in inches.....	.....	.....	6.8	13.9	20.4	25.0	27.2	28.2	28.5	28.4
Number of fish.....	.....	.....	164 ¹	297	260	191	127	46	13	2

¹Due to the difficulty in accurately locating the first annulus, the first year's growth for all age classes was calculated from 164 carp of the total of 330.

Opercular bones from carp of known age, recovered at the end of the second year of life, had one annulus. This annulus was evidently deposited during the first winter of life. Although these carp were recovered on March 27, 1951, the annulus for the current winter was evident on the margin of some of the opercular bones. Early resumption of growth was probably due to the presence of warm springs in the pond where the carp were recovered.

As the data were collected for the most part during one year it was not possible to validate further the opercular method by tracing dominant year classes or distinctive years of growth through successive collections.

Length-frequency histograms for carp collected during the winter of 1950-51 indicate that there are three modes of length for carp under 500 millimeters in standard length. The conjecture that these modes represent three age groups is substantiated by the fact that ages of these carp, as suggested by the modes, is the same as the ages indicated by their opercular bones. Furthermore, comparison of this histogram with one for the pooled calculated lengths of all carp determined to be 1, 2, and 3 years old shows that the modes for both are at approximately the same lengths (Figure 2). This approximate agreement between empirical and calculated lengths of fish in the same age classes suggests that the calculated lengths are correct. The mean calculated lengths for the first 3 years of growth of all age groups also agree fairly well with the modes of empirical length frequency (Table 1).

An anomaly appears in the calculated lengths (Table 1). The average calculated lengths for the first year of life show a gradual increase with increasing age of the fish, while the length attained at the end of any year of life past the first becomes progressively shorter for each succeeding age class. This is thought to be due to two factors. With increasing age the year marks closest to the fulcrum became more difficult to see and did not enter the calculations. As a result the first year marks used in the growth calculations were a greater distance from the fulcrum for each succeeding age class. This caused an increasing proportion of more rapid first year growths to enter the calculation of the average first year of growth for each succeeding age class. Acting in conjunction with this bias in the calculation of the first year's growth is an actual change in growth rate which is probably due to the extreme change of habitat that has been occurring during the past several years at Ogden Bay Refuge.

CONCLUSIONS

The opercular method of determining age and growth of carp has several important advantages to recommend it. Ages are read with greater confidence from the opercular bones than from the scales. The annuli are definite and in most cases only one interpretation of age

can be made. Age and growth is readily determined past the fourth year from the opercular bones. The preparation of the opercular bones for study is much less time consuming than that for scales. It is necessary to make temporary wet mounts of scales as neither the glycerin gelatin or the dry method of mounting carp scales is satisfactory. The opercular bones on the other hand are simply dried after cleaning and may be used this way without further preparation.

There is much less variation of the opercular bone-body length relationship than of the scale-body length ratio. When calculating past growth the use of opercular bones is, in effect, about the same as using key scales. Back calculation of growth from opercular bones of carp does not require optical equipment since measurements may be made directly from the opercular bone. Although the validity of the opercular method for determining age and growth of the carp has not been established conclusively, it is believed that there is significant evidence in favor of it.

ACKNOWLEDGMENTS

Sincere gratitude is expressed to Dr. William F. Sigler, head of the Department of Wildlife Management, Utah State Agricultural College, for direction and advice. Thanks are also due Dr. George H. Kelker, Department of Wildlife Management, Utah State Agricultural College, for suggestions in preparing the manuscript. The extensive cooperation of the Utah Agricultural Experiment Station (Project 309) and the Utah Cooperative Wildlife Research Unit is gratefully acknowledged. Much valuable assistance in the collection of the data was supplied by Albert Regenthal, Edward Wright, and William Zarbock. Assistance in the field by many undergraduate students is also acknowledged here.

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MOVEMENTS OF YELLOW PERCH MARKED IN SOUTHERN GREEN BAY, LAKE MICHIGAN, IN 1950

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Sturgeon Bay, Wisconsin*

ABSTRACT

To obtain information on the post-spawning movements of yellow perch that spawn in southern Green Bay, Lake Michigan, 4,172 fish caught in drop nets were marked by tagging with monel-metal strap tags attached to the right operculum and 24,799 were marked by clipping off the second or membranous dorsal fin. Marking was done during the period from May 3 to 17, 1950, at six main stations, all located in the southern end of Green Bay.

The average length of the tagged perch was 7.3 inches and all fell within the range 5.5-14.4 inches. Most (90.9 percent) of the fish were below the minimum legal length of 8.0 inches. The follow-up procedure consisted of informing commercial and sports fishermen of the program and enlisting their cooperation in watching for marked fish; accounts of the investigation were released through newspapers and descriptive posters were distributed. The personnel connected with the investigation examined catches frequently.

The large majority (101 or 79.5 percent) of the 127 tagged perch recaptured in the experimental nets during the marking operations were retaken at the tagging station at which they were released.

Of the 108 tagged perch captured by commercial fishermen and anglers following the opening of the season on May 20, 96 were taken by drop nets, 6 by gill nets, and 6 by hook and line. The mean lengths for the three groups were 7.7, 7.1, and 9.25 inches, respectively. All recoveries were made in the Wisconsin waters of Green Bay.

Most of the "open-season" recoveries (86 fish; 79.6 percent) were made during the period May 20-May 31. Recaptures during subsequent months were: June—14; July—7; August—none; September—1. Of the 86 perch recaptured May 20-31, 70 were retaken inside and 16 outside the tagging area. The majority (14 of 22) of those recovered after May 31 were retaken outside the tagging area.

The average length of the 20 tagged yellow perch recaptured by drop nets (data restricted to fish from a single type of net to avoid bias from gear selectivity) outside the tagging area (8.42 inches) was 0.96 inch greater than the mean length (7.46 inches) of the 76 fish retaken inside the area. This statistically highly significant difference lends support to the belief of commercial fishermen that the larger of the yellow perch that spawn in southern Green Bay move out soon after spawning.

The percentage of recapture of tagged perch increased sharply with increase in the size of the fish. Not one of 169 tagged fish less than 6.5 inches long was recovered. The rates of recapture at greater lengths were: 6.5 to 8.9 inches—2.5 percent; 9.0 to 9.9 inches—11.4 percent; 10.0 to 14.4 inches—16.7 percent. Among the several factors suggested in explanation of this relationship, the most important appear to be the lesser ability of the smaller fish to survive the rigors of handling and tagging, greater loss of tags from the smaller fish, and the greater likelihood of overlooking the smaller of the tagged fish in the sorting of the catch.

The factors just mentioned and the lack of knowledge of the efficiency of measures taken to obtain records of recoveries preclude the 2.6-percent return of all tagged fish from being accepted as an approximation of the rate of recapture. Neither should the 6.6-percent return of tagged fish of legal size (8 inches and longer) be taken as an estimate of the rate of exploitation.

Although 465 fin-clipped perch were recovered in the experimental nets during the marking operations, only 68 of 24,799 fish so marked were recovered after the fishing season opened. All but one of these 68 were retaken near the point of marking. The difficulty of detecting a perch with a missing membranous dorsal is believed to be a major cause of the poor returns from fin-clipped fish.

These investigations have demonstrated that for studying migration of yellow perch, tagging is superior to fin-clipping as a method of marking. The technique of the tagging, however, needs to be improved, and better means must be found to trace tagged fish of small size. Furthermore certain small regions in the bay not at present open to commercial fishing must be explored in order to obtain more comprehensive information as to migration.

INTRODUCTION

This report deals with a cooperative investigation made in 1950 by the Wisconsin Conservation Department and the United States Fish and Wildlife Service for the purpose of tracing the migration of yellow perch, *Perca flavescens* (Mitchill), in the Green Bay waters of Lake Michigan. Commercial fishermen of southern Green Bay long have contended that the minimum legal size for perch in that area should be less than the present 8 inches because the stock is characterized by extremely slow growth and because the larger perch leave the area soon after spawning. To obtain information on the latter point a project for the marking of spawning fish was initiated in 1948. The preliminary investigations of 1948 and 1949 produced inadequate information. The present study was more fruitful in that it yielded instructive, if not highly conclusive, data on the movements of perch and also useful information on methods for marking and procedures for a follow-up program.

The yellow perch is of primary significance in the commercial fisheries of southern Green Bay. According to statistics compiled by the Wisconsin Conservation Department the annual take of perch during the last 15 years, 1936-1950, averaged 1,199,000 pounds (range from 480,000 pounds in 1950 to 2,380,000 pounds in 1943).

MATERIALS AND METHODS

A total of 28,971 yellow perch were marked, which was nearly three times the number in either of the two preceding seasons. Full-time personnel was used for the first time in the follow-up program. All perch were captured by drop nets (a type of fyke net) which are the common gear used in southern Green Bay waters. As each net was lifted, the fish were emptied into a live car alongside the boat. The net was

then reset and the boat swung free and anchored nearby. From the live car the fish were transferred to a galvanized tub, and either tagged or fin-clipped as rapidly as possible. Serially numbered monel-metal strap tags were attached to the right operculum of 4,172 yellow perch, and 24,799 perch were marked by the removal with surgical scissors of the membranous dorsal fin as close to the back of the fish as was possible without injury to the flesh.

After exploratory study of southern Green Bay, the following localities were chosen as the marking stations: off Point Comfort; off Red Banks; off the north side of Point Sauble; off the northern edge of



FIGURE 1.—Green Bay, Lake Michigan. Points and months of recovery of marked perch are indicated by dots.

Frying Pan Reef; inside Long Tail Point; and east of the Suamico River (Fig. 1). The number of yellow perch tagged and fin-clipped at these several stations, and the corresponding dates, are shown in Tables 1 and 2. The largest number, 1,093 (26.2 percent of the total) was tagged off Point Sauble, with Frying Pan Reef a close second (1,004 fish or 24.1 percent of the total number tagged). The largest numbers tagged on any one day were 973 and 970 (both 23.3 percent)

TABLE 1.—*Number and percentage of yellow perch tagged on each date and at each locality.*¹

Marking Locality	Number of fish tagged on date						Total	Percent- age
	May 5	May 9	May 11	May 12	May 13	May 15		
Point Comfort.....	.....	96	.....	588	.....	.....	684	16.4
Red Banks.....	.....	108	.....	286	.....	.....	394	9.4
Point Sauble.....	.....	.....	709	.....	.....	384	1,093	26.2
Frying Pan Reef.....	94	.....	184	.....	726	.....	1,004	24.1
Long Tail Point.....	654	.....	.....	.....	.....	.....	654	15.7
East of Suamico River.....	.....	.....	.....	99	244	.....	343	8.2
Total.....	748	204	893	973	970	384	4,172	.....
Percentage.....	17.9	4.9	21.4	23.3	23.3	9.2	.....	.....

¹Fish marked from exploratory nets were assigned to the nearest principal tagging station.

on May 12 and May 13, respectively. The greatest numbers were fin-clipped at Frying Pan Reef (8,079; 32.6 percent) and at Point Sauble (5,898; 23.8 percent). The largest number of perch marked in this manner in a single day was 10,931 (44.1 percent) on May 16. The final day (May 17) was a poor second (3,211 fish; 13.0 percent).

TABLE 2.—*Number and percentage of yellow perch fin-clipped on each date and at each locality.*¹

Marking locality	Number of fish fin-clipped on date									Total	Percent- age
	May 3	May 8	May 9	May 11	May 12	May 13	May 15	May 16	May 17		
Point Comfort.....	.....	564	.....	364	14	739	.....	1,797	.....	3,478	14.0
Red Banks.....	.....	.....	.....	278	230	848	.....	1,681	.....	3,037	12.2
Point Sauble.....	.....	391	151	459	433	749	1,450	.....	2,265	5,898	23.8
Frying Pan Reef.....	.....	141	159	241	1,453	554	.....	4,585	946	8,079	32.6
Long Tail Point.....	184	86	123	.....	.....	.....	.....	.....	.....	393	1.6
East of Suamico River.....	19	303	.....	706	6	12	.....	2,868	.....	3,914	15.8
Total.....	203	1,485	433	2,048	2,136	2,902	1,450	10,931	3,211	24,799	.....
Percentage.....	0.8	6.0	1.7	8.3	8.6	11.7	5.8	44.1	13.0	.....	.....

¹Fish marked from exploratory nets were assigned to the nearest principal tagging station.

Because commercial fishermen were expected to make the majority of the recaptures of marked fish, a letter describing the program and requesting cooperation was sent to every Wisconsin fisherman on Green

Bay. In addition many fishermen were informed personally in both Wisconsin and Michigan and posters were placed on boat docks and at other places where fishermen were likely to see them. State and federal biologists accompanied commercial fishermen as often as possible to inspect the catches. Wisconsin and Michigan conservation officials cooperated by inspecting catches at fishing establishments and aboard boats. Valuable aid was also given by newspapers that published accounts of the project.

RECAPTURE OF TAGGED FISH DURING THE MARKING PERIOD

Of the total of 127 tagged yellow perch recovered from the nets during the marking operations, 101 (79.5 percent) were retaken at the same locality and 26 (20.5 percent) were retaken at other marking stations. Nearly all of the fish recaptured at the same locality were caught soon after tagging, usually the next time the net was lifted.

TABLE 3.—*Number and percentage of tagged yellow perch recovered at various distances from tagging area within different periods of time.*

Distance from point of tagging ¹ (miles)	Period of recovery						Total re-covered	Percentage re-covered
	May 20-31	June 1-15	June 16-30	July 1-31	Aug. 1-31	Sept. 1-30		
Nil ²	70	5	.....	3	.....	.....	78	72.2
<20.....	15	4	.....	2	.....	.....	21	19.4
20 to 40.....	1	3	1	1	.....	1	7	6.5
40 to 50.....	.....	.....	1	1	.....	.....	2	1.9
Total.....	86	12	2	7	.....	1	108	.....
Percentage.....	79.6	11.1	1.9	6.4	.....	0.9	.....	.....

¹Computed from northern limit of tagging area as shown in Figure 1.

²Recovered in tagging area.

The longest interval for recovery during the marking period for any tagged fish was 11 out of a possible 12 days. All of the 127 recaptured tagged fish that were alive were returned to the water and none was again retaken during the marking operations. However, 3 were recaptured later in the year.

The condition of the gills and operculum of the recaptured tagged fish varied from an excellent to a badly irritated state. Several of the tags were found to be loosened.

RECAPTURE OF TAGGED PERCH AFTER THE MARKING PERIOD

The commercial fishing season for yellow perch opened in Wisconsin on May 20. Nets were set on this date, and the first lifts were made by most of the fishermen on May 22. The last 12 days of May yielded the largest number of returns (86 tagged fish or 79.6 percent of the

total were recaptured during this period, Table 3). Twenty-one fish were recaptured during June and July, but there were no returns during August. On September 12, a fish that had been tagged at Point Sauble on May 15 was taken in a gill net near Sherwood Point Light at the entrance to Sturgeon Bay. This was the last tagged perch recaptured.

Of the 108 tagged fish recovered, 96 were taken by drop nets, 6 by gill nets, and 6 by hook and line. Three of these last 6 represented the most distant returns.

We have only one record of the recapture of a tagged fish more than once during the fishing season. An 8.0-inch yellow perch tagged at Point Sauble (east shore) on May 12 was recaptured at Little Tail Point (west shore) on May 23 by a commercial fisherman, and released. It was captured again at Red Banks (east shore) on May 31 by another commercial fisherman.

Recoveries from different tagging stations and dates.—With the exception of Long Tail Point for which the percentage return was only 0.8 percent (Table 4), the percentages of recapture of fish tagged at different localities varied little (range from 2.5 percent at Point Comfort to 3.2 percent east of the Suamico River). The percentages of

TABLE 4.—*Number and percentage of yellow perch returned from each tagging locality.*

Tagging locality	Number tagged	Number returned	Percentage returned
Point Comfort.....	684	17	2.5
Red Banks.....	394	12	3.1
Point Sauble.....	1,093	33	3.0
Frying Pan Reef.....	1,004	30	3.0
Long Tail Point.....	654	5	0.8
East of Suamico River.....	343	11	3.2
Total or average.....	4,172	108	2.6

recovery according to date of tagging (Table 5) exhibited a considerably greater range (from 1.1 on May 5 to 6.5 on May 15) and also showed a tendency toward a definite if irregular increase from the earliest to the last date. This increase may be associated with the length of time during which the fish were subject to post-tagging mortality before they had a chance to be recaptured after the opening of the season on May 20.

Time out and distance traveled.—The records of distances from the tagging area, with corresponding dates, for the 108 recaptured yellow perch (Table 3 and Fig. 1) reveal that the great majority of the fish—72.2 percent of all those caught—were recaptured within the tagging area; 19.4 percent were recaptured in localities less than 20 miles distant; 6.5 percent at 20 to 40 miles; and 1.9 percent at locations 40 to

50 miles distant from the tagging areas. The tagged perch retaken at the greatest distance from the point of release was caught by hook and line on July 30 off Peninsula State Park, near Ephraim, Wisconsin. This fish had been tagged on May 15 at Point Sauble. On the same day, however, another fish that had also been tagged on May 15 at Point Sauble was caught by hook and line only a few hundred yards from the Point. These figures indicate a great variation in movement of individual perch.

The recovery of the tagged yellow perch at different localities depends not only on the migration of these fish but also on the existence of the means to capture them. A decisive role is played by the extent of fishing operations and by the type of gear used in different areas and during different periods. The total number of recoveries in the present experiment was too small to warrant an analysis of the recap-

TABLE 5.—*Number and percentage of tagged yellow perch returned from each tagging date.*

Tagging date	Number tagged	Number returned	Percentage returned
May 5.....	748	8	1.1
May 9.....	204	4	2.0
May 11.....	893	16	1.8
May 12.....	973	28	2.9
May 13.....	970	27	2.8
May 15.....	384	25	6.5
Total or average.....	4,172	108	2.6

tures according to locality and date in relation to fishing pressure. It can be stated, nevertheless, that the facilities for recovery were generally good, since the Wisconsin waters of Green Bay comprise one of the most heavily exploited (by both sport and commercial fishermen) areas of the Great Lakes and Michigan waters of the bay are also heavily fished. The greatest weakness existed in Door County, on the eastern upper half of the Wisconsin waters where regulations prohibit the use of the drop net, a gear particularly effective for taking perch. The principal type of gear in these waters is a 2½-inch-mesh gill net that ordinarily catches few or none of the smaller fish. This problem of gear selectivity and the matter of overlooking tagged fish in certain fisheries will be treated in a later section.

Despite the relatively small total number of recoveries, there appears to be a definite relationship between time elapsed after tagging and the distance moved before recapture. Of the 78 fish retaken within the tagging area, 70 (90 percent) were caught during the period May 20-May 31 and 8 (10 percent) on later dates; of 21 perch taken outside but not more than 20 miles from the region of marking 15 (71 percent) were captured during May 20-May 31 and 6 (29 percent) later; of

9 fish recaptured 20 to 50 miles from the tagging area only 1 (11 percent) was caught during May 21-May 31 and 8 (89 percent) were taken on later dates. The application of the Chi-square test demonstrated that the proportions of fish captured May 20-31 and after May 31 differed significantly among all three recovery zones listed in Table 6.

TABLE 6.—Comparison of numbers of tagged yellow perch recaptured May 20-31 and after May 31 within the tagging area and at various distances from it.

[Data condensed from Table 3]

Distance from point of tagging ¹ (miles)	Period of recovery	
	May 20-31	June-September
Nil ²	70	8
<20.....	15	6
20 to 50.....	1	8

¹Computed from northern limit of tagging area as shown in Fig. 1.

²Recovered in tagging area.

Average length and locality of recapture.—To avoid possible bias from the selective action of the gear, the data of Table 7 on the relationship between the length of recaptured tagged perch and locality of recovery were based exclusively on fish taken in drop nets, which accounted for 96 of the 108 recaptures. In two of three comparisons the mean lengths of yellow perch retaken outside the tagging area were

TABLE 7.—Comparison of the average lengths of tagged yellow perch recovered by means of drop nets inside and outside the tagging area over different periods of time.

Date of recapture	Area of recapture				Difference between means	Value of p^1
	In tagging area		Outside tagging area			
	Number of fish	Average lengths (inches)	Number of fish	Average lengths (inches)		
May 20-31.....	70	7.47	11	8.77	1.30	<0.01
June 1-July 31.....	6	7.32	9	7.99	0.67	>0.05
May 20-July 31 ²	76	7.46	20	8.42	0.96	<0.01

¹Determined from the Behrens-Fisher test; Student-Fisher test not applicable by reason of unequal variance. See p. 111 *et seq.*, Vol. 2 of: Kendall, Maurice, "The advanced theory of statistics," 2nd Ed., Charles Griffin and Co., Ltd., London, 1948.

²The May and the June-July samples of fish taken in the same area exhibited no significant differences of the mean or of the variance.

greater than the lengths of fish recovered in the area by a highly significant margin. The June-July recoveries yielded indefinite results, probably because small numbers of fish (6 in the tagging area and 9 outside) were taken. The combined May-July samples indicate an average difference of nearly an inch between the lengths of the 76 perch

recovered within the area of tagging (mean of 7.46 inches) and of the 20 fish taken in more northerly waters (mean of 8.42 inches). Scanty as these data are, they lend strong support to the belief of commercial fishermen that the larger of the yellow perch that spawn in southern Green Bay tend to desert the area after spawning.

RELATIONSHIP BETWEEN LENGTH OF FISH AND PERCENTAGE OF RECAPTURE

The data on the length-frequency distributions of yellow perch tagged and fish recaptured and on the percentage of recapture at different lengths (Table 8) demonstrate that the program was far more successful for the large than for the small fish. The recaptured fish averaged longer (7.7 inches) than the perch tagged (7.3 inches), the frequency distributions of the two groups were dissimilar (that the difference between the distributions was significant was proven by the Chi-square test), and the percentage of recapture exhibited a strong if irregular tendency to increase with increase in the length of the fish.

TABLE 8.—Comparison of length-frequency distribution of yellow perch tagged and of tagged fish recaptured.

Total length (inches)	Fish tagged		Fish recaptured		Percentage of recapture
	Number	Percentage	Number	Percentage	
5.5—5.9.....	2	10.0			0.0
6.0—6.4.....	167	4.0			0.0
6.5—6.9.....	934	22.4	13	12.0	1.4
7.0—7.4.....	1,753	42.0	41	38.0	2.3
7.5—7.9.....	937	22.5	29	26.8	3.1
8.0—8.4.....	232	5.6	12	11.1	5.2
8.5—8.9.....	67	1.6	2	1.9	3.0
9.0—9.4.....	32	0.8	4	3.7	12.5
9.5—9.9.....	12	0.3	1	0.9	8.3
10.0—10.4.....	11	0.3	2	1.9	18.2
10.5—10.9.....	6	0.1	2	1.9	33.3
11.0—11.4.....	6	0.1	1	0.9	16.7
11.5—11.9.....	5	0.1			0.0
12.0—12.4.....	4	0.1	1	0.9	25.0
12.5—12.9.....	3	0.1			0.0
13.0—13.4.....					
13.5—13.9.....					
14.0—14.4.....	1	10.0			0.0
Total.....	4,172		108		2.6
Average length.....	7.3		7.7		

¹Less than 0.05.

How greatly the percentage of recovery varied with the size of the fish is brought out by the summary of the data for the selected intervals of length shown in Table 9. Not one of the 169 tagged yellow perch within the length range 5.5-6.4 inches was retaken. The percentage was small (2.5 percent) at 6.5-8.9 inches although so many of the tagged fish fell within this range that the actual number of recaptures

(97) was large. At 9.0-9.9 inches the percentage of recapture jumped to 11.4—more than 4 times the value at 6.5-8.9 inches—and at 10.0-14.4 inches it was even greater (16.7 percent).

Clear-cut as the evidence is that the percentage of recapture improved with increase in the size of the fish, there is no good information available to explain the relationship. The following factors are suggested as the more important: greater loss of tags from small than from large fish; greater ability of large than of small fish to survive the rigors of handling and of carrying tags; greater probability of recapture of the larger fish by means of the fishing methods employed; greater chance

TABLE 9.—*Percentage recovery of tagged yellow perch at certain selected intervals of length.*

[Data condensed from Table 8]

Length interval (inches)	Number tagged	Number recaptured	Percentage of recapture
5.5—6.4.....	169	0	0.0
6.5—8.9.....	3,923	97	2.5
9.0—9.9.....	44	5	11.4
10.0—14.4.....	36	6	16.7

of detection of the larger tagged fish in the sorting of the commercial catch; differences in the pattern of movement that carried a large percentage of the smaller fish into areas where they were not subject to capture. Of the several "explanations" listed above only the last can be held strictly speculative. Evidence strongly favors the view that the other factors actually did contribute to the relatively higher rate of recapture of the larger yellow perch.

The tags themselves were poorly suited for marking small fish. Each arm of the tags measured about one-half inch and the average weight was a little greater than 0.5 gram (a sample of 25 weighed 13.0 grams). Tags of this size must place small fish under a severe handicap and certainly they would be more likely to wear their way through the operculum and become lost from small than from large individuals.

The possible effects of the selective action of the gears of recapture are difficult to assess. Commercial drop nets, the type of gear employed to take fish for tagging (and the gear from which 96 of the 108 recoveries were obtained) would not be expected to be selective in recapturing the same fish. Commercial gill nets which accounted for 6 recaptures ordinarily take few perch less than 8 inches long. The tagged fish captured by this gear, however, were small—averaging only 7.1 inches as compared with 7.7 inches for perch recovered in drop nets. It is probable that selective action normally exerted by gill nets in the taking of yellow perch does not apply to tagged fish since some of the small tagged perch had been caught by the tangling of the tag in the

webbing of the gill nets. The six yellow perch retaken by hook and line averaged 9.25 inches. Three of the six were more than 9 inches long (largest, 12.1 inches) and none were below 7.3 inches.

The method of sorting employed by drop-net fishermen of southern Green Bay tends to cause tagged fish of less than legal length (8.0 inches) to be overlooked. In the standard procedure the net is emptied on the deck of the boat and the fish are picked up with scoop-shovels. The legal-sized fish are removed from each shovelful and the remainder tossed overboard. Since this sorting is carried out rapidly as a protection to the undersized fish which strongly predominate in the drop-net catches, smaller individuals are not carefully observed. The strap tags were not highly visible and if a fish happened to be lying on its right side there was no opportunity for detection of the mark. Failure to see the mark on undersized fish could not explain the changes in the percentage of recapture among the lengths greater than 8.0 inches. In the Michigan waters of Green Bay the chances of overlooking tags on the smaller fish were even greater since the larger size limit (8½ inches as compared with 8 inches in Wisconsin) leads to mass rejections of undersized fish.

The factors outlined above together with our general uncertainty about the actual effectiveness of the program to obtain reports of all recoveries that were noticed make it impossible to accept the 2.6-percent return of yellow perch of all sizes as even an approximate measure of the rate of recapture. Likewise the 6.6-percent recovery of legal-sized fish is not believed to be a sound estimate of the rate of exploitation.

The restriction of tagging to the larger fish would increase the efficiency of recovery, but it is as important for an understanding of movements of the spawning population to have data on the small perch as on large ones. Furthermore, relatively few large fish were available for tagging.

RECAPTURE OF FIN-CLIPPED FISH

The open-season recovery of fin-clipped yellow perch was small. During marking operations, 465 fish were retaken in the nets. As in nearly all of these perch the wound seemed to have healed rapidly with little or no infection, high hopes were held for a successful return during the summer. However, after the commercial season opened, only 68 of the 24,799 fin-clipped fish were recaptured (Table 10). Of these 68 recaptures, 64 occurred during May, and 67 were found close to the point of marking. Only one fin-clipped fish was taken at a considerable distance from the point of marking. It was recaptured on June 28 near Peshtigo Reef on the west shore approximately midway between Marinette and Oconto (Figure 1). Only 3 other recaptures were reported in the month of June. The men checking catches reported that perch usually depressed their dorsal fin when removed from the water; therefore very close scrutiny was necessary to determine

whether this fin had been removed. Because the time required to make close examination was prohibitive, it is possible that many fin-clipped fish escaped recognition. It is also to be noted that some fin-clipped perch kept for observation in a pond at Sturgeon Bay showed slight to moderate fin regeneration. This fact suggests further difficulty in the quick recognition of this type of marking.

TABLE 10.—Location, date, and number of fin-clipped fish recovered.

Location	Date	Number recovered
Geanos Beach.....	May 23	3
Frying Pan Reef.....	May 23	4
Point Sauble.....	May 23	3
Vincent Point.....	May 24	5
North of Dykesville.....	May 24	3
Red Banks.....	May 24	2
Point Sauble.....	May 24	2
North of Little Tail Point.....	May 25	15
Geanos Beach.....	May 25	8
Red Banks.....	May 25	8
Point Comfort and Frying Pan.....	May 25	7
East of Suamico River.....	May 26	3
Frying Pan Reef.....	May 27	1
Point Sauble.....	June 2	1
Point Sauble.....	June 5	1
Whitney Bluff.....	June 9	1
Peshtigo Reef.....	June 28	1
Total.....		68

The results from the fin-clipping lead to the conclusion that the advantage offered by this technique over tagging in terms of the large numbers of fish that can be handled is outweighed by the difficulty of recognizing fin-clipped specimens and the loss of records for individual fish.

ACKNOWLEDGMENTS

The tagging party consisted of: Joseph DeWitt and Joseph DeWitt, Jr., commercial fishermen from Suamico, Wisconsin; Ralph Hile, Leo F. Erkkila, and Donald Mraz of the U. S. Fish and Wildlife Service; and Robert Balch of the Wisconsin Conservation Department. Matt Patterson, Donald Euers, and the warden staff of the Wisconsin Conservation Department assisted in the preliminary arrangements and follow-ups. Leonard Joeris of the U. S. Fish and Wildlife Service was present for the follow-up. Hundreds of commercial and sports fishermen aided the program by checking their catches and reporting tagged and fin-clipped fish.

Dr. Ralph Hile, of the Fish and Wildlife Service, read my original manuscript, and Mr. Walter Haertel helped prepare the chart (Fig. 1) showing the locations of tag recoveries. Statistical tests employed in the analysis of certain data were made by George F. Lunger of the Service.

DEPTH DISTRIBUTION OF THE BLUEGILL, *LEPOMIS MACROCHIRUS* RAFINESQUE, IN FARM PONDS DURING SUMMER STRATIFICATION

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ABSTRACT

Depth distribution of the bluegill, *Lepomis macrochirus* Rafinesque, in farm ponds was determined by the use of fish traps. Results indicated that during summer stratification bluegills were found in greatest numbers in shallow waters. They were unable to live for extended periods of 6 to 45 hours at water depths where the dissolved-oxygen concentration was 0.3 p.p.m. or less accompanied by a carbon-dioxide concentration of 4.4 p.p.m. or more. This condition was therefore considered to be the critical combined dissolved-oxygen and carbon-dioxide concentrations for bluegills and the depth that these concentrations usually occurred was designated as the critical depth.

The critical depth was normally 5 feet in the 2-acre pond and 7 feet in the 22-acre pond during the period of summer stratification which was studied during the period from June 24 through September 12, 1949. With increases in surface areas of the ponds from 2 to 22 acres, the critical depths increased apparently as the result of deeper mixing of the waters due to increased wave action. The critical depth increased in all ponds following strong winds, heavy rainfalls, or cool periods. It decreased during periods of extended cloudiness or other conditions resulting in reduced photosynthetic activity in the deeper waters.

INTRODUCTION

The bluegill, *Lepomis macrochirus* Rafinesque, has been used extensively in stocking farm fish ponds as recommended by Swingle and Smith (1942). Because it is important as a pond fish, an understanding of its depth distribution is of value. It is generally believed among fishermen that fish always go to the deepest and coldest waters during the hottest part of the summer, regardless of the type of stream or impoundment. The purpose of this work was to determine the extent that deeper waters were used by the bluegill in farm ponds and to correlate dissolved oxygen, carbon dioxide and temperature with the utilization of the deeper waters during the period of summer stratification which was studied during the period from June 24 through September 12, 1949.

In the experiments of Shelford and Allee (1913, 1913a) fishes responded to the conditions of their environments by spending most of their time in water containing high dissolved-oxygen and low carbon-dioxide concentrations. Fishes turned back from waters high in carbon dioxide and low in dissolved oxygen with precision and vigor. If they

entered waters high in carbon dioxide and low in dissolved oxygen, they did not react normally and soon died. Shelford (1914) believed that the concentration of carbon dioxide may be taken as an index of the suitability of water for fish. He claimed that this index was significant since high amounts of carbon dioxide, 7.1 p.p.m. or more, were usually accompanied by a lack of dissolved oxygen. Pearse and Achtenberg (1920) showed that yellow perch, *Perca flavescens* (Mitchell), in Wisconsin lakes were found most abundantly immediately above the thermocline, but they commonly went into the stagnant water below the thermocline where there was little or no dissolved oxygen.

MATERIALS AND METHODS

This study was made in ponds on the Farm Ponds Project of the Alabama Agricultural Experiment Station. The major portion of the work was done on a 2-acre pond that was considered typical of the average farm fish pond in Alabama. For comparison, four other ponds of 3, 6, 22, and 26 acres were studied for brief periods in order to supplement data regarding the oxygen requirements of bluegills and to determine the depths at which critical concentrations of dissolved oxygen and carbon dioxide would occur in a variety of ponds. All ponds used in this experiment were fertilized and managed as recommended by Swingle and Smith (1942).

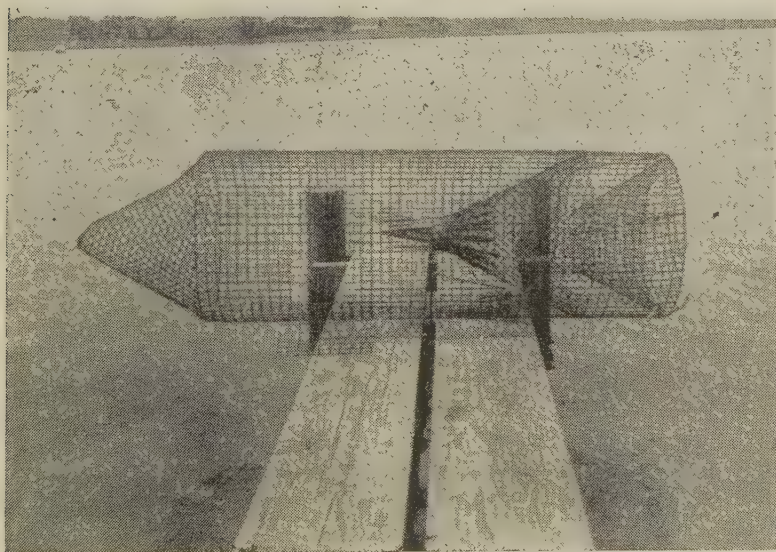


FIGURE 1.—The type of trap used in the study of depth distribution.

Bluegills were trapped with 1-inch or $\frac{1}{4}$ -inch mesh wire traps of the type shown in Figure 1. All traps were equipped with two funnels. White oak strips were interwoven into the innermost funnel in such a way that the escape of bluegills was almost impossible unless they could swim through the mesh of the wire. Each trap was equipped with a door for the easy removal of the fish. Traps were set on the bottom at various depths from 2 to 9 feet in the 2-acre pond and from 4 to 8 feet in the 22-acre pond. Depths of 4.5 to 8 feet were trapped in the 3-, 6-, and 26-acre ponds. Usually traps were lifted and the fish removed either once or twice daily, but occasionally they were checked every 2 days. Most of the traps were baited with cottonseed cake, but some were used unbaited.

Water samples were collected from the various depths and analyzed periodically throughout the experiment. Samples were obtained by use of a bottle train sampler which is shown in Figure 2. This sampler was

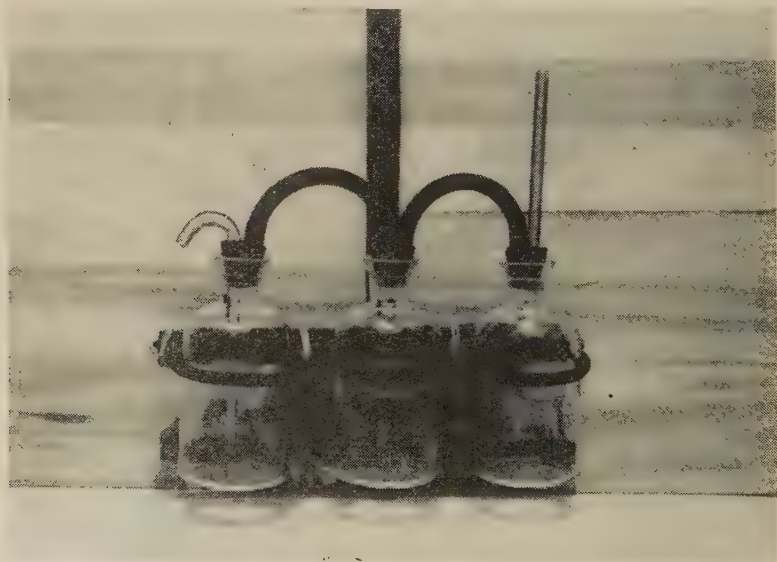


FIGURE 2.—The bottle train sampler used for collecting water samples.

attached to a graduated rod and lowered to the depth at which the water was to be collected. Dissolved-oxygen analyses were made from the contents of the bottle into which the water first entered the train. The contents of the second bottle of the train were used for the analyses of carbon dioxide.

Chemical analyses of the water for dissolved oxygen were made by the Rideal-Stewart modification of the Winkler method. Carbon dioxide was determined by the tentative method for determining free car-

bon dioxide as described by the Association of Official Agricultural Chemists (1945). Temperatures were measured with a Foxboro portable resistance thermometer and recorded in degrees Fahrenheit. Surface temperatures were taken 3 inches below the surface of the water, and readings below the surface were taken at intervals of 1 foot.

RESULTS AND DISCUSSION

During the period from June 24 through September 12, 1949, traps were removed from the various depths of the ponds and examined every 6 to 45 hours. At periodic intervals water analyses and temperature checks were made at the trap-depths immediately before the traps were removed. The dissolved-oxygen and carbon-dioxide concentrations of the water and mortality of the bluegills in all ponds are given in Table 1. The results indicate that the critical concentration of dissolved oxygen to bluegills was approximately 0.3 p.p.m. when accompanied by a concentration of 4.4 p.p.m. or more of carbon dioxide. Therefore, it is likely that bluegills were limited in their use of the deeper waters because of low concentrations of dissolved oxygen and high concentrations of carbon dioxide rather than temperature.

TABLE 1.—*The average percentage mortality of bluegills in all ponds when trapped at different concentrations of dissolved oxygen and carbon dioxide expressed as parts per million.*

Dissolved-oxygen concentrations	Carbon-dioxide concentrations	Average mortality in 6 to 45 hours
0.0—0.3	4.4—39.6	90.4
0.4—0.6	4.4—12.1	26.2
0.7—0.9	3.3—6.6	12.4
1.0—1.9	1.1—7.7	9.9
2.0—Above	0.0—5.5	0.2

The differences between surface and bottom temperatures of the ponds usually ranged from 12 to 18° F. throughout the experiment. The 2-acre pond showed a greater difference between surface and bottom temperatures than the larger ponds which were more affected by wave action. Bottom and surface temperatures and the depth at which critical dissolved oxygen occurred in the 2-acre pond are shown in Figure 3. Detailed results of temperatures taken at various depths in the 2-acre pond are shown in Table 2.

Mortalities that occurred at oxygen concentrations above 0.3 p.p.m. were apparently caused by changes in dissolved-oxygen and carbon-dioxide concentrations during the periods that the traps remained in the water. Frequently, a decrease in dissolved-oxygen and an increase in carbon-dioxide concentrations were noticed between the time the traps were set and the time they were examined. A 64.2 percent greater average mortality was recorded at oxygen concentrations of 0.3

p.p.m. and less than at oxygen concentrations of 0.4 to 0.6 p.p.m. This observation substantiates the belief that 0.3 p.p.m. is the critical concentration of oxygen for bluegills when accompanied by 4.4 p.p.m. or more of carbon dioxide.

The depth at which critical concentrations of oxygen and carbon dioxide usually occurred has been designated as the critical depth. This depth was found to be the minimum depth in which excessive mortalities were recorded. Furthermore, the critical depth appeared to be the dividing line between those depths used extensively and those used rarely or not at all.

As the surface areas of the ponds increased from 2 to 22 acres the critical depth increased from 5 to 7 feet. The critical depth increased apparently because there was deeper mixing of the waters by increased wave action. Since the 2-acre pond was small and well protected from

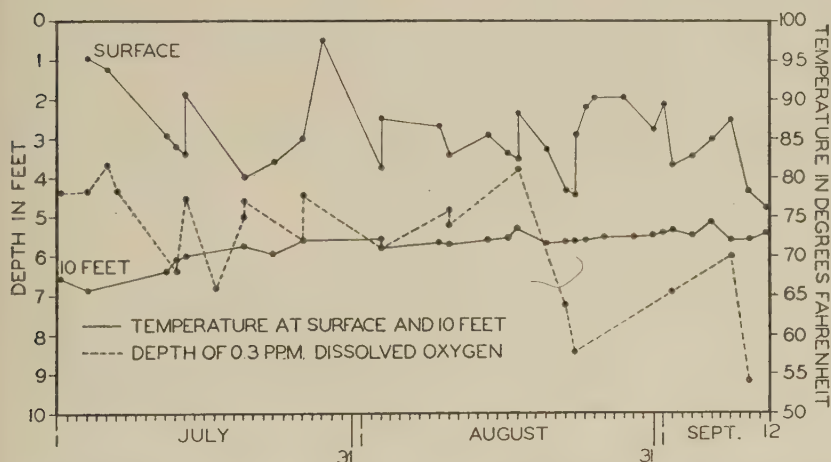


FIGURE 3.—Surface and bottom temperatures shown with the depth of 0.3 p.p.m. of dissolved oxygen in the 2-acre pond.

the wind, wave action was never sufficient to cause circulation deeper than about 4 feet. The 22-acre pond, on the other hand, had frequent stirrings from wave action that distributed dissolved oxygen to depths of 8 feet.

The usual critical depth during the period from June 24 through September 12, 1949, in the 2-acre pond was approximately 5 feet (Figure 4). As the cool periods began to occur in late August and early September, the critical depth gradually began to descend until the fall overturn made the entire pond suitable for use. The bluegills

immediately dispersed from the shallow waters and were found at all depths of the pond. The critical depth in the 22-acre pond although variable, was about 7 feet before cool periods began in late August and early September (Figure 5).

There were temporary variations in the critical depths occurring in both ponds caused by heavy rains, cool periods, extended cloudiness, and abundance of phytoplankton. Inflow of flood waters from heavy rains and convection currents caused by cool periods were both responsible for distributing oxygen to the stagnated waters and thus low-

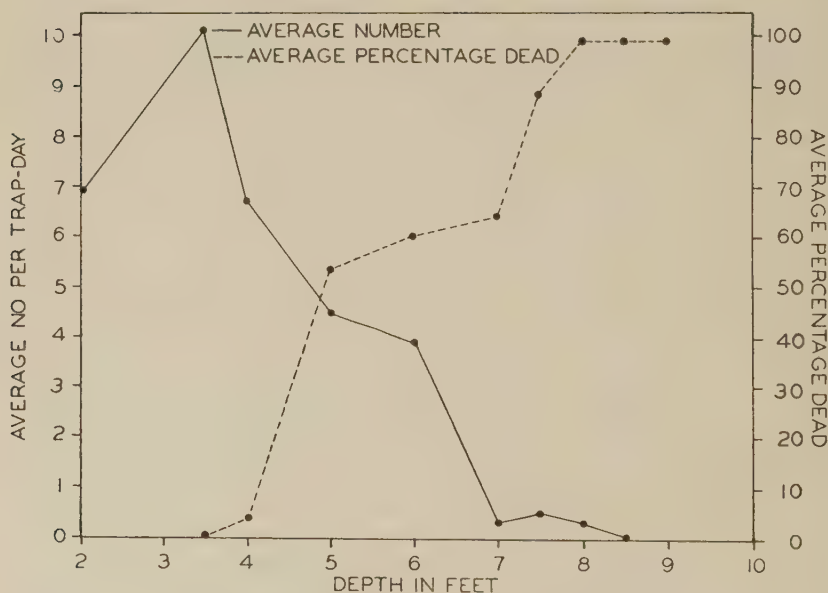


FIGURE 4.—Average number of bluegills caught per trap-day and percentage dead in 1-inch-mesh traps at various depths in a 2-acre pond from June 24 through September 12, 1949.

ering the critical depth. Bluegills immediately began to use these deeper waters that contained more than 0.3 p.p.m. of dissolved oxygen. This condition was temporary and usually lasted for 12 to 36 hours. Large mortalities often resulted among trapped bluegills because the conditions had changed between the time the bluegills entered the trap and the time the trap was checked. Extended cloudiness of 1 to 3 days occurring concurrently with an abundance of living phytoplankton created an oxygen depletion which caused the critical depth to rise and bluegills to die in traps about 18 inches nearer the surface.

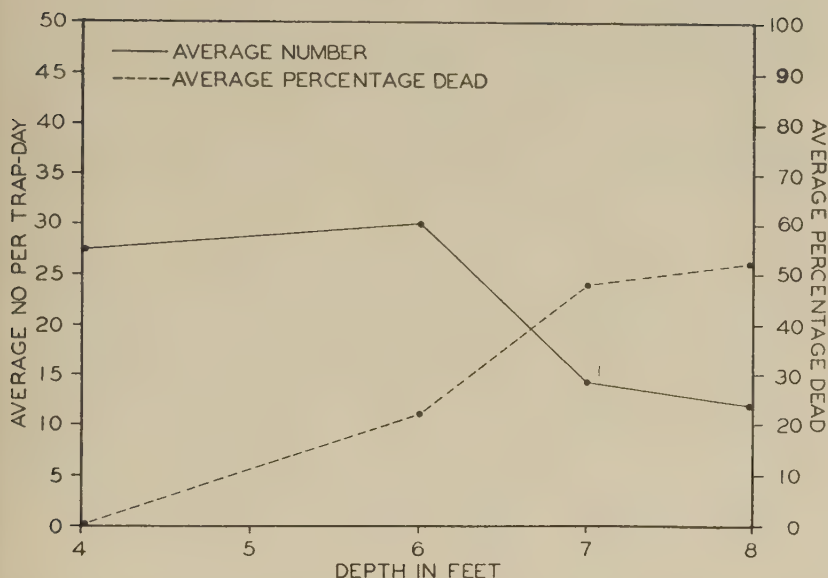


FIGURE 5.—Average number of bluegills caught per trap-day and percentage dead in $\frac{1}{4}$ -inch-mesh traps at various depths in a 22-acre pond from August 9 through September 12, 1949.

CONCLUSION

The waters in farm fish ponds definitely were stratified during the summer. The bluegills could not efficiently utilize the colder and deeper waters because of low concentrations of dissolved oxygen and high concentrations of carbon dioxide.

ACKNOWLEDGMENT

This study was conducted in conjunction with a research assistantship of the Farm Ponds Project, Alabama Agricultural Experiment Station.

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AGE AND GROWTH OF THE BROWN TROUT, *SALMO TRUTTA FARIO* LINNAEUS, IN LOGAN RIVER, UTAH

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ABSTRACT

The Logan River flowing southwesterly through the mountains of Cache County, Utah, is comparatively cold to the mouth of Logan Canyon. The stream is characterized by steep gradient, a high velocity and relatively few pools. A total of 1,053 brown trout were examined during the course of this study; 286 were retained for age and growth determinations. The body-scale relationship is $L = 40.46 \text{ mm.} + 0.44185R + 0.01908R^2$ where L equals standard length in millimeters, and R equals scale radius times 80. The relationship of standard length to weight is described by the formula $W = 0.000022L^{2.96}$. The rate of growth in length of Logan River brown trout is comparable to that of several other populations. The relative weight is somewhat higher.

INTRODUCTION

In 1948 a comprehensive fishery investigation on Logan River was initiated by the Department of Wildlife Management, Utah State Agricultural College, and the Utah Cooperative Wildlife Research Unit.¹ One phase of this study is the life history of the brown trout *Salmo trutta fario* Linnaeus. Native fish in Logan River above the lowest impoundment dam include cutthroat trout *Salmo clarki* Richardson, mountain whitefish *Prosopium williamsoni* (Girard), Utah sculpin *Cottus bairdi semiscaber* (Cope), and rarely the smallfin reidside shiner *Richardsonius balteatus hydrophlox* (Cope). Introduced fish, in addition to the brown trout, are the eastern brook trout *Salvelinus fontinalis fontinalis* (Mitchell) and coast rainbow *Salmo gairdneri irideus* Gibbons.² There is no upstream passage of fish over the lowest impoundment dam.

Fish were collected largely with the aid of an electric shocking machine. A few were collected with experimental gill nets and by hook and line. A total of 1,053 fish were examined and 286 were retained for age and growth determinations during the course of this study. Scales and other data were taken according to standard procedure from June, 1948, through February, 1951. Carlander (1950) lists over 100 articles and reports which contain some reference to brown trout. However, detailed information on the rate of growth of wild brown trout is quite limited.

¹Utah Fish and Game Department, Wildlife Management Institute, Utah State Agricultural College and U. S. Fish and Wildlife Service, cooperating.

²Since the introduction of rainbow trout, the hybrid, rainbow x cutthroat has appeared.

DESCRIPTION OF THE AREA

Logan River heads in Franklin County in Southern Idaho and flows southwesterly through Cache County, Utah, until it empties into Bear River. The rugged mountainous area of the Logan River watershed covers 225 square miles of weathered Paleozoic Age limestone, dolomite, and shale. The main branch of the river enters Utah at an elevation of 8,500 feet and drops to 4,500 feet where it enters Cache Valley, a distance of approximately 36 stream miles. Brown trout are most abundant below elevations of 6,800 feet. The average gradient for the Logan River is approximately 70 feet per mile (Brown, 1935). In general, the higher elevations have much steeper gradients than the lower sections of the river. There are three artificial impoundments above 4,500 feet which supply power and irrigation water to Cache Valley. These impoundments, none of which exceeds 22 feet in depth or 4 acres in size, have a rich bottom layer of silt and extensive shoal areas.

The stream bottom is composed largely of coarse gravel, rubble, and boulders. Sand and gravel beds are scarce because the gradient is steep and the velocity of the river is high. Silting is slight in the stream bed except during the spring run-off. Turbidities, based on

TABLE 1.—*Body-scale relationship (L/Sc) of 286 brown trout from Logan River, arranged in 20-millimeter standard-length groups with all age groups combined.*

Actual mean standard length (millimeters)	Actual mean scale radius	Calculated mean scale radius	L/Sc ratio	Number of fish
51.4	19	15	2.70	9
68.6	26	28	2.64	16
89.7	36.6	40.5	2.45	11
113.4	51.4	51	2.21	29
129.6	53.4	58	2.43	41
150.0	65.0	65	2.31	35
170.7	71.0	72	2.40	44
189.5	82.1	77.5	2.31	30
210.5	82.8	83.5	2.54	25
229.6	91.0	88.7	2.52	10
249.6	92.8	94.0	2.69	12
268.4	97.1	98.3	2.76	8
293.4	97.4	104.0	3.01	5
311.0	103.0	108.0	3.02	6
332.5	119.5	112.7	2.78	2
384.6	129.0	123.2	2.98	3

$$L = 40.46 \text{ mm.} + 0.44185R + 0.01908R^2$$

silicon dioxide equivalents, range from 25 to 32 parts per million in the spring, but drop to 6 parts per million in September and October. There is almost no pollution except from soil erosion. The average velocity of the river over a series of stations, between April and October in 1948 and 1949, was 2.6 feet per second.

The major source of water during the summer and fall months is springs. This source, coupled with high water velocity and an abundance of bank shade, keeps the temperature comparatively low to the

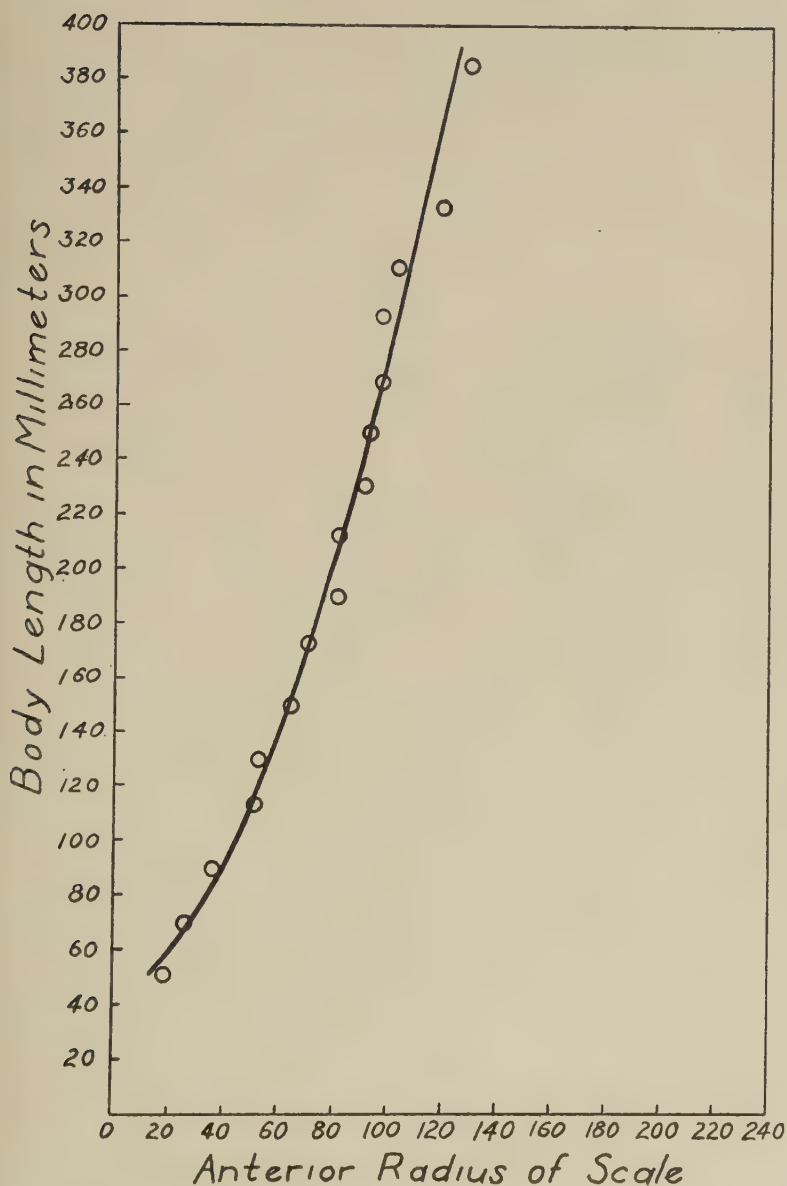


FIGURE 1.—Body-scale relationship of 286 brown trout from Logan River, Utah.
 $L = 40.46 \text{ mm.} + 0.44185R + 0.01908R^2$.

TABLE 2.—Summary of the mean calculated standard lengths and annual increments of lengths in millimeters for the Logan River brown trout with sexes combined, collected in 1948, 1949, and 1950.

Age class and item	Number of fish	Standard length at capture	Calculated lengths at end of year of life							
			1	2	3	4	5	6	7	8
I.....	124	138.7	86	...	...	...	...	...	...	...
II.....	92	188.8	88	149	...	...	...	...	...	...
III.....	32	255.9	91	155	218	...	...	...	...	...
IV.....	6	316.0	72	128	201	269	...	...	...	...
V.....	2	395.5	75	128	169	253	317	...	...	...
VI.....	1	420.0	62	116	186	240	300	372	...	...
VII.....	1	670.7	84	124	170	276	404	470	600	...
VIII.....	2	654.5	79	119	211	252	341	377	528	600
Grand averages and total.....	260	.....	87	148	211	262	337	399	552	600
Increments of growth.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Number of fish.....	87	.....	61	136	64	70	82	52	144	72
Total length in inches.....	260	.....	.....	.....	44	12	6	4	3	2
.....	4.0	.....	6.9	.....	9.7	12.1	15.6	18.3	25.5	27.7

mouth of Logan Canyon. Temperatures taken between April and October, 1948 and 1949, from the Idaho line down to the upper (third) dam, averaged about 48° F. and did not exceed 60° F. The average monthly mean discharge at the junction of the Cache National Forest and Cache Valley, based on the 1946-1949 water seasons, was 247 cubic feet per second. The greatest flow occurred in May (717) and the least in February (108).

The habitat of the mountain whitefish, which is similar to that of the brown trout, is described in more detail by Sigler (1951).

RATE OF GROWTH

The body-scale relationship of 286 brown trout is described by the formula $L = 40.46 \text{ mm.} + 0.44185R + 0.01908R^2$, where L = standard length in millimeters and R = scale radius in millimeters times 80 (Table 1, Figure 1). The standard length was measured from the tip of the snout to the posterior edge of the hypural plate. The assessment of age and the calculation of growth were accomplished by reading the scales. The validity of the method was tested according to practices described by Van Oosten (1929) and Hile (1941). Actual calculation of past growth was made with the aid of a nomograph similar to that described by Carlander and Smith (1944) and Hile (1950).

Brown trout in Logan River grow approximately 3 inches per year after the first year (Table 2). They attain a legal length of 7 inches early in their third year of life. According to this study, fish in advanced year groups do not grow faster than those in younger groups, but simply live longer. Based on age, Logan River brown trout apparently grow in length at about the same rate as many other populations (Eddy and Carlander, 1939; Bean, 1902; and others).

A series of one-tenth mile sections of stream were sampled with an electric shocking machine. A total of 1,053 fish from these sections was measured to the nearest inch and recorded on a length-frequency basis. Normally the numbers of fish in length groups decrease as the size of the fish increase. Fish less than 4 inches long represented only 8 percent of the total, and did not follow the expected length-frequency ratio. This result is believed to be a sampling bias rather than a representation of actual conditions. It is recognized that the electric shocker is quite selective in regard to fish size; that is, the smaller the fish the less shock they receive, other factors being equal. The number of fish in length groups between 7 and 20 inches dropped steadily and rapidly as the size increased. Forty-seven percent of the legal-sized fish were less than 10 inches long, and 61 percent of them were less than 15 inches long. Fish between 4 and 9.7 inches long in the age and growth sample (Table 2) represent 95 percent of the total. Fish from these same length groups total 76 percent of the entire population studied.

The length conversion factors, based on the fish in Table 1, are as follows: standard length times 1.173 equals total length; total length times 0.852 equals standard length; fork length times 0.887 equals standard length.

TABLE 3.—Length-weight relationship and coefficient of condition (K) of 286 brown trout from Logan River.

Mean standard length in millimeters	Weight in grams		Difference in actual and calculated weight	Mean K	Number of fish
	Actual mean	Calculated mean			
51	2	2	0	1.938	9
69	6	6	0	1.912	16
90	12	13	+1	1.720	11
113	25	26	+1	1.737	29
130	40	40	0	1.842	41
150	62	61	-1	1.845	35
171	90	90	0	1.814	44
190	127	122	-5	1.860	30
210	170	165	-5	1.834	25
230	204	215	+11	1.688	10
250	267	276	+9	1.728	12
268	329	339	+10	1.692	8
293	400	440	+40	1.574	5
311	512	526	+14	1.712	6
332	634	638	+4	1.347	2
385	868	989	+121	1.546	3

$$W = 0.000022 L^{2.96}$$

LENGTH-WEIGHT RELATIONSHIP

The relationship of weight in grams to standard length in millimeters is described by the formula $W = 0.000022 L^{2.96}$ (Table 3). The agreement between actual and calculated weights is good for groups of fish containing over six individuals. The condition factor, K, of brown trout from Logan River was calculated from the following formula:

$$K = \frac{W \times 10^5}{L^3}$$

when W = weight in grams and L = standard length in millimeters. The highest K value of 1.938 was recorded for the smallest fish. K decreases somewhat with the increase in length. The condition factor of the Logan River fish is somewhat higher than that of several other populations (Schuck, 1945; Carlander, MS).

According to Needham (1938) few brown trout over 5 pounds are taken from streams. Bean (1902) lists as maximum a weight of 22 pounds and a length of 35 inches, but states that 5 or 6 pounds is a good average. Although Logan River has yielded some very large

brown trout, including some near world's record, accurate data on them are scarce. In 1937 a 39-inch brown trout weighing $37\frac{3}{4}$ pounds was taken from the lowest impoundment. Almost every year one or two ranging in weight from 12 to 18 pounds are caught from the lower part of the river.

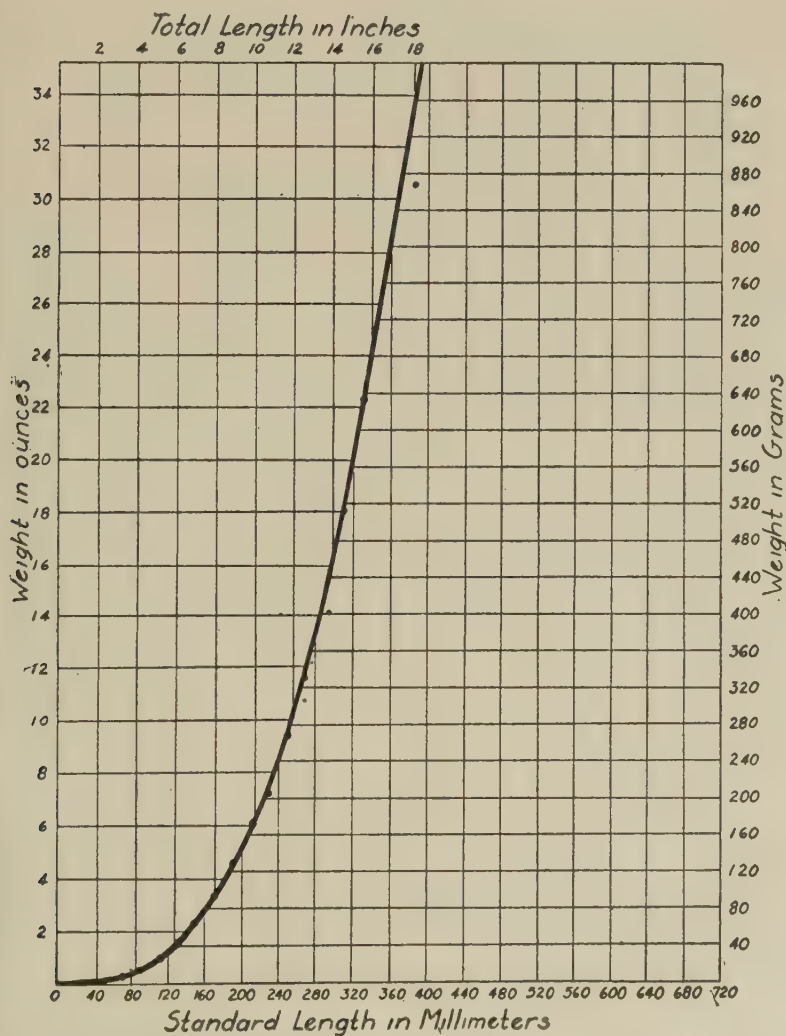


FIGURE 2.—Length-weight relationship of 286 brown trout from Logan River, Utah.
 $W = 0.000022 L^{2.96}$

ACKNOWLEDGMENTS

I am grateful for the assistance received from graduate and undergraduate students in the Department of Wildlife Management, Utah State Agricultural College. Special thanks are due to students Sam Jackson and George Fleener.

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MOVEMENTS OF MARKED WALLEYES, *STIZOSTEDION VITREUM VITREUM* (MITCHILL), IN THE FISHERY OF THE RED LAKES, MINNESOTA¹

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ABSTRACT

The Red Lakes commercial fishery is carried on in two connected lakes with a combined area of 275,000 acres. These lakes are shallow and support a large population of walleyes (*Stizostedion vitreum vitreum*) which is the principal commercial species. A marking study was carried on over a 3-year period to determine whether distinct populations exist in the two lakes. Monel-metal jaw tags were placed on 9,739 walleyes taken from the spawning runs of both lakes in the springs of 1949, 1950, and 1951. A total of 1,572 tags, or 16.1 percent, was returned during the 3-year period. Of the total tag recoveries 314, or 20.6 percent, moved between the two lakes. The greatest distance covered by any fish was 60 miles in 68 days and the fastest rate of travel was 41.5 miles in 33 days. The population of the two lakes was judged to be homogeneous on the basis of fish movement, similar rates of growth of fish taken from both lakes, and similar condition factor (K). Comparison of returns of marked fish at various size intervals with numbers marked in each interval suggests that mature males are completely available to the commercial nets but that females reach a size beyond which vulnerability drops appreciably. It was further demonstrated that males were not subject to exploitation before maturity but that the majority of females was subject to 1 year of fishing prior to attainment of sexual maturity.

INTRODUCTION

The Red Lakes commercial fishery constitutes one of the principal economic resources of the Red Lake Band of Chippewa Indians. The fishery is supported by the warm-water fish population of the lakes which have a combined area of 275,000 acres and lie almost entirely within the Red Lake Indian Reservation of northern Minnesota. Extensive fluctuation of the walleye, *Stizostedion v. vitreum* (Mitchill), population and a continual increase in the fishing intensity by the Indian fishermen have created problems which require extensive investigation of the biology and economics of the fishery. At the request of

¹Paper No. 2848, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

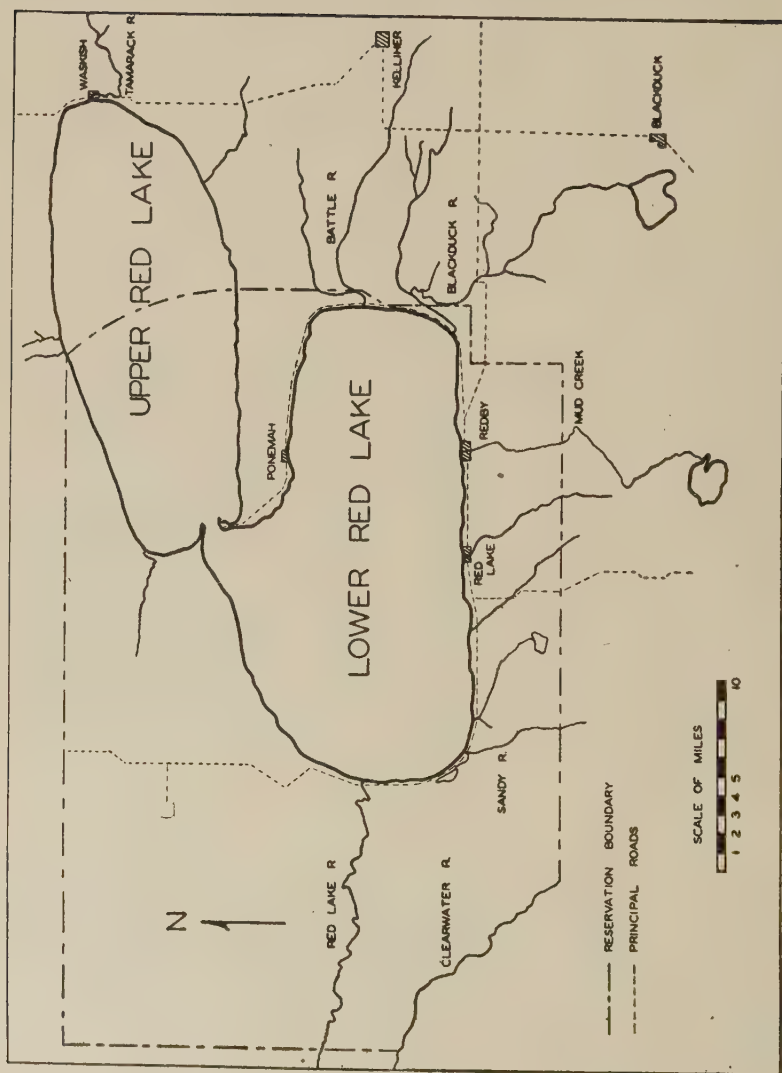


FIGURE 1.—The Red Lakes of Minnesota. The entire lower lake and the western portion of the upper lake lie within the Red Lake Indian Reservation.

the Bureau of Indian Affairs, U. S. Department of the Interior, a series of studies was initiated early in 1949 to provide biological information on which effective management could be based. The present paper on the movement of marked walleyes in the lakes is a report on one phase of these studies.

The water area consists of two roughly oval basins connected by a channel approximately three quarters of a mile wide. Both lakes are shallow with the upper lake having a maximum depth of 20 feet and a mean depth of approximately 8 feet and the lower lake a maximum depth of 35 feet and a mean of 18 feet. Surrounding soils are bog, sand, and glacial till but the shores and a large part of the bottom are composed of sand. Waters are derived from seepage and the inflow from a number of streams which drain the surrounding watershed (Figure 1). The lake level is maintained by a dam at the outlet into the Red Lake River. This river flows into the Red River of the North which is the most southerly tributary of the Hudson's Bay drainage. The lakes are moderately alkaline (total alkalinity 120-135 p.p.m.) and have no thermocline. Heavy winds which circulate the water cause the water temperature to follow the mean air temperatures rather closely. Observed summer water temperatures in the lower lake range from 62° to 72° F. at all levels.

The fishery which has yielded an average of 1,095,000 pounds of marketable fish per year during the 20-year period of 1932-1951 has been carried on continuously since 1917. Although some white fishermen worked in Upper Red River during the early history of exploitation, Indian fishermen have had exclusive commercial fishing rights in recent years. The annual harvest is carried on under a quota system that controls the total catch of walleyes and northern pike (*Esox lucius*) each year. All fish are marketed through the Red Lakes Fishery Association, a cooperative fishery operated under general regulations set up and administered by the United States Department of Interior and approved by the Minnesota Department of Conservation. Personnel of the fishery association monitor the catch and set the annual opening date and duration of each fishing season. The exact fishing period is determined largely by climatic and economic factors but is confined to the summer and autumn months.

Fishing is carried on exclusively with gill nets of 3½-inch mesh (extension measure) in the hands of 180 to 250 fishermen working from skiffs powered by outboard motors. Fish are collected daily from the fishing camps on the lake shores by trucks and are taken to the fishery at Redby, Minnesota, where they are graded and prepared for shipment.

The Red Lake investigations were designed to furnish information on which to base administrative rulings and practices such as annual harvest quota, gill-net mesh, and fishing season; and to explore certain fundamental problems of population structure in relation to har-

vest and yield. Since the walleye is the most important commercial species, it has been studied most intensively with perch (*Perca flavescens*), whitefish (*Coregonus clupeaformis*), and goldeye (*Amphiodon alosoides*) receiving secondary consideration.

Because there are two large bodies of water with somewhat different habitat conditions, the primary step in the work has been to determine the distinctness or homogeneity of the walleye populations which support the fishery. It also has been important to estimate the effects of various levels of fishing pressure on the stock. In an attempt to answer these questions the fish-marking study reported here was started in April 1949.

The investigations have been carried on within the scope of a cooperative agreement between the University of Minnesota and the U. S. Fish and Wildlife Service, and supported in part by research grants from the Graduate School of the University. The U. S. Bureau of Indian Affairs has cooperated in the return of tags and the furnishing of certain field facilities; and the Minnesota Department of Conservation has permitted the use of its hatchery facilities at Waskish for the marking of fish in that area.

METHOD OF FISH MARKING AND TAG RECOVERY

Method of marking.—During the progress of the study 9,739 walleyes were tagged with No. 2 monel-metal strap tags attached to the left mandible (Table 1). The tags were of conventional design with serial numbers and directions for return imprinted upon the two legs. All tags were affixed by forcing the sharp point through the flesh inside the mandible, pressing the tag together, and locking it with sharp-nosed pliers. Tags were rounded with the pliers after locking.

During the 1949 spawning runs 3,374 males and 1,298 female walleyes were marked at the Blackduck River between April 24 and April 28 (Figure 1). All fish were captured in pound nets set in the mouth of the river during the course of spawn-taking operations. Most of the fish marked were stripped of eggs and milt before they were released above the weirs into the stream. Subsequent observations and returns indicated that the majority of the fish continued their migration upstream. All fish were measured to the closest 0.1 inch, and scale samples were taken from approximately one-third of the walleyes marked. Care was taken to keep fish out of the water for as short a time as possible and to release them immediately after tagging. In 1950, 1,839 males and 145 females from the spawning run of the Tamarack River in Upper Red Lake were similarly jaw-tagged. These operations were carried on between May 10 and May 14 at the Waskish fish-spawning station. Most of the males were released after tagging without having been stripped. All females were stripped of eggs before release. Extremely high water and flooding of sloughs along the river as well as

TABLE 1.—*Walleyes marked in Upper and Lower Red Lake and total tag recoveries in the Red Lakes and tributary waters, 1949, 1950, and 1951, expressed as number and percentage by sexes taken in commercial (C) and angling (A) fishery. Percentages are shown in parentheses.*

Item	Marked Lower Lake—1949				Marked Upper Lake—1950			Marked Upper Lake 1951	Grand total
	1949	1950	1951	Total	1950	1951	Total		
Fish marked.....	4,697				1,995			3,047	9,739
Males.....	3,374 (72.2) ¹				1,839 (92.1)			2,525 (82.8) ¹	7,748 (79.8)
Females.....	1,298 (27.8) ¹				145 (7.3)			519 (17.1) ¹	1,963 (20.2)
Immature.....	2 (0.04)							3 (0.1)	5 (0.05)
Incomplete data.....	23 (0.5)				11 (0.6)				34 (0.3)
Marked fish returned.....	733 (15.6)	296 (6.3)	152 (3.2)	1,181 (25.1)	150 (7.5)	86 (4.3)	236 (11.8)	155 (5.1)	1,572 (16.1)
Males (C).....	555 (16.5)	176 (5.2)	99 (2.9)	830 (24.6)	84 (4.5)	52 (2.8)	136 (7.3)	94 (3.7)	1,060 (13.7)
Females (C).....	153 (11.8)	54 (4.2)	31 (2.4)	238 (18.4)	13 (9.0)	7 (4.8)	20 (13.8)	34 (6.5)	292 (14.9)
Males (A).....	12 (0.4)	24 (0.7)	15 (0.4)	51 (1.5)	41 (2.2)	25 (1.4)	66 (3.6)	18 (0.7)	135 (1.7)
Females (A).....	6 (0.5)	17 (1.3)	7 (0.5)	30 (2.3)	7 (4.8)	2 (1.4)	9 (6.2)	6 (1.2)	45 (2.3)
Fish found dead.....	3 (0.1)			3 (0.1)				1 (0.03)	4 (0.04)
Incomplete data.....	4 (0.1)	25 (0.5)		29 (0.62)	5 (0.3)		5 (0.3)	2 (0.06)	36 (0.4)

¹Calculated as percentage of total males and females. Other percentages calculated as the basis of all fish, or total males, or total females in each case.

the late date of the run increased the hazards encountered by the fish which continued upstream after release. In the 1951 spawning season 2,525 male and 519 female walleyes were marked in the Tamarack River from May 1 to May 6. These fish were handled in the same manner as that employed in the previous markings. Scales were taken from approximately one-half of the marked fish. All fish were released immediately after marking and continued their upstream movement.

Method of recovery.—Various methods of tag-recovery were considered. Inability to secure sufficient funds to provide a reward for each returned tag made it necessary to depend upon the willing cooperation of commercial fishermen and anglers. The project and its purposes were given extensive publicity in the form of posters, instructions to game wardens and fishery personnel, and through direct letter contact with all commercial fishermen, both before and during the season. Explicit directions for the return of tags were given to commercial fishermen. They were requested to bring the tags directly to the fishery building or give them, together with information on place and date of catch, to the truck drivers who collected the fish from the fishing camps. Most of the tags returned were collected by the truck drivers although a substantial number were brought directly to the fishery building by the fishermen. All returns from anglers were voluntary and were mailed directly to the University of Minnesota or were turned over to game wardens. In spite of the care taken to publicize the purposes of the study, some commercial fishermen exhibited marked antagonism. This attitude hampered tag recovery in some areas during the first year of operation, but gradually was reduced during ensuing seasons. The habits of the commercial fishermen and the method of tag collection made it impractical to get any data other than date and location of catch from most marked fish which were returned. Complete information on weight, length, and age was taken from the specimens which were examined by the investigators.

RETURN OF MARKED FISH

From the opening of the angling season on May 15 in 1949 to September 1, 1951, a total of 1,572 tags, representing 16.1 percent of all fish tagged, was recovered by commercial fishermen and anglers (Table 1). Of this number 1,352 were captured by commercial fishermen and 180 by anglers. The remaining 40 tags were returned with incomplete information.

Return of fish marked in 1949.—Of the 4,697 fish marked in the spring of 1949 and released in the Blackduck River 1,181, or 25.1 percent, were recaptured during the three following fishing seasons. Eight hundred and thirty males, or 24.6 percent of all males marked, and 238 females, or 18.4 percent of all females marked, were returned by the commercial fishery. Fifty-one males, or 1.5 percent, and 30 females, or 2.3 percent, were returned by anglers. Three fish were found dead

and 29 tags were returned with incomplete data on the location of catch. The rate of recovery of all marked fish in this experiment declined from 15.6 percent in the first year to 3.2 percent in the third year. Recovery of both males and females declined at approximately the same rate. Returns from anglers the first year was lowest, presumably because marked fish had not yet reached the area of heavy fishing during the early angling season.

Return of fish marked in 1950.—Of the 1,995 fish marked in the Tamarack River and returned to the upper lake in 1950, a total of 236, or 11.8 percent, was recovered in 1950 and 1951. Commercial fishermen reported 156 and anglers reported 75. Five tags were returned with incomplete data. Of the total number of males marked 7.3 percent and of the total females marked 13.8 percent were taken in the commercial fishery. Anglers returned 3.6 percent of all males marked and 6.2 percent of all females marked. The relatively lower recovery of the 1950 tags during the 1950 and 1951 seasons than of 1949 tags in 1949 and 1950 is believed to be a reflection of the loss incurred immediately after tagging in the flooded backwaters of the river and of the low fishing pressure in the upper lake during the 1950 and 1951 seasons. Another possible cause of low recovery, especially during the first season, was the fact that an appreciable percentage of the males marked was not completely available to the commercial gear. The rate of return of the fish marked in 1950 declined from 7.5 percent in 1950 to 4.3 percent in 1951. Males and females declined at approximately the same rate.

Return of fish marked in 1951.—Of the total number of fish marked during the 1951 spawning run, 5.1 percent were returned during the first season. Commercial fishermen recovered 3.7 percent of all males and 6.5 percent of all females which were marked. Anglers returned 0.7 percent of the males and 1.2 percent of all marked females. The apparent low return of fish during the first season is partially attributable to the facts that a large percentage of the fish tagged were below the size of maximum availability to the nets, and that fishing pressure in the upper lake was extremely light during 1951. Total commercial fishing pressure on both lakes combined was only about 75 percent of that exerted in 1950. The higher return of females than males may have resulted from the fact that a greater percentage of the females was large enough to be caught readily by the commercial nets.

MOVEMENTS OF MARKED FISH

Previous studies (Stoudt and Eddy, 1939; Doan, 1942; R. W. Eschmeyer, 1942; Carbine and Applegate, 1946; Herman, 1947; Rose, 1949; Manges, 1950; Paul H. Eschmeyer, 1950) have shown that marked walleyes may move considerable distances and that dispersal after spawning is rapid. This known tendency for extensive movement made it important that Red Lake walleyes be traced after spawning to determine the degree of interchange of individuals between the two

lakes and the amount of movement out of the lakes. Since there is no commercial fishery in any of the tributary waters and commercial operations in the lakes do not start until 6 to 8 weeks after the spawning period, anglers' returns provide the principal information on speed of migration and movements outside the lakes.

Distance and speed of travel.—Of the 180 fish caught and reported by anglers in 3 years, 7 were taken outside the Red lakes. The remaining fish were taken at some point within the lakes proper or at mouths of the streams emptying into them. The greatest distance travelled by any fish on which an authentic report was made was 60 miles (in 68 days). This fish was taken 20 miles east of Thief River Falls, Minnesota, in the Red Lake River. An unverified report indicated that one fish may have moved about twice this distance into the Red River. Fish taken between the time of marking and the opening of the commercial fishing season give some indication of the speed of movement. The greatest rate of travel was noted in a fish which moved 41.5 miles from the mouth of the Blackduck River in the lower lake to the mouth of the Tamarack River in the upper lake in 33 days. Several fish were taken in the headwaters of the Blackduck River where they had gone to spawn after marking. The greatest distance travelled from the lake in the spawning stream was 23.5 miles to the mouth of Blackduck Lake where one marked fish was taken. Although no tags were returned from Blackduck Lake, a local game warden reported that he had seen tagged fish taken from this water. Fish moving within the lakes prior to the angling season appear to have made the greatest possible travelling distance from one lake to the other (41.5 miles) within 33 days as noted above, and to the most distant point in the lake (outlet) where they were marked (23.0 miles) in 21 days.

The lapse of time between the opening of the commercial fishing season and the time of marking precluded the possibility of judging speed of fish movement by observation of the commercial catch. In the 1949 season, 74 days elapsed between marking and the start of fishing. In 1950 and 1951, 44 and 40 days, respectively, elapsed between marking and the opening of the commercial season. In all 3 years it appeared that by the start of the commercial season which varied from June 16, 1951, to July 9, 1949, marked fish had been generally distributed over the entire fishing area. During the commercial season all areas of the lake were fished simultaneously and the rate of return of marked fish seemed to be uniform from the different areas throughout the fishing period. Observed variations in the rate of return from different areas were more closely associated with changes in fishing intensity than with either the time elapsed since marking or the distance of the fishing area from the place of marking. It is assumed, therefore, that whatever distribution of spawners was effected during any particular fishing season had occurred before the opening of commercial operations. A careful check in 1949 of the fishing location in the lower lake which was most distant from the Blackduck River showed that

TABLE 2.—*Movement of marked walleyes between Upper and Lower Red Lake as revealed by recovery of tags in 1949, 1950, and 1951.*

Year and location of marking	Year and location of recovery						Fish moving between lakes			Percentage ³ of total marked fish recovered
	1949		1950		1951		Total number	Percentage total recoveries	Percentage of total fish marked	
	Lower lake	Upper lake	Lower lake	Upper lake	Lower lake	Upper lake				
Lower lake Blackduck R. 1949..	688	35	245	26	126	25	86	7.5 (1,145) ¹	1.8 (4,697) ²	25.14
Upper lake Tamarack R. 1950...	.....	.....	74	71	46	37	120	52.6 (228) ¹	6.0 (1,995) ²	11.83
Upper lake 1951.....	.....	.....	.....	.....	108	44	108	71.1 (152) ¹	3.5 (3,047) ²	5.08
Total.....	688	35	319	97	280	106	314	20.6 (1,525) ¹	3.2 (9,739) ²	16.14

¹Total tags recovered exclusive of those returned without data or from outside the Red Lakes proper.²Total fish marked in the respective years.³Fish returned from each marking in 3, 2, and 1 year respectively and all years combined—expressed as percentage of total fish marked.

the return of marked fish at the opening of the season was just as great as during any subsequent period. In the seasons of 1950 and 1951 similar distribution of marked fish was observed.

Interchange of fish between the two lakes.—As has been shown above, fish move between the Red Lakes. The important question concerns the number of individuals which move and whether the movements exhibit any trend which would affect the fishery or change the population structure in either lake. If the movement is appreciable, it is probable that the populations of the two lakes are homogeneous and do not react independently to changes in fishing intensity or general environmental conditions. It has been commonly believed by fishermen and fishery personnel at the Red Lakes that there are two populations. This belief was based on the general knowledge that an experienced operator could usually distinguish between a box of fish from the upper lake and one from the lower lake. The present authors also learned to make this distinction in about 7 cases out of 10. Careful observation suggested that the basis of choice was color and a somewhat more slender appearance in the fish from the upper lake. The only difference which held up under careful check was the apparent difference in color.

In view of these observations the intermingling of fish which has been noted from the marking studies is especially significant. During the 3 years of observation 314 fish, or 20.6 percent of all marked fish which were recovered, moved from one lake into the other (Table 2). The percentage of all recovered marked fish which moved between the lakes was 7.5 percent from the 1949 marking, 52.6 percent from the 1950 marking, and 71.1 percent from the 1951 marking. Returns of fish from the upper lake may have been low in 1949 because cooperation from fishermen in that area was poor. Returns for the following years are believed to be more representative of the actual recoveries. In 1951 fish which were marked in the upper lake were recovered at more than twice the rate in the lower lake that they were in the upper lake. Although this difference is more a reflection of heavier fishing pressure in the lower lake than a measure of relative abundance of marked fish in the two lakes, it does indicate a general dispersal of fish from the Tamarack River spawning runs.

Some additional evidence is available from the spawning runs in the years following marking. The recovery of tags during the spring migration was not as great as might have been expected in view of tag returns made during the following commercial season. Most of the tags recovered during spawning runs were from fish originally marked at that particular station but a few had been marked at other locations. In one stream tributary to the lower lake where no tagging was done (Mud Creek) tags from both Blackduck River and Tamarack River were recovered. The observations suggest that homing instinct may be weak and that fish often may go to the closest available spawning stream.

HOMOGENEITY OF POPULATION IN RED LAKES

Although interchange of fish between the two lakes as demonstrated by tag returns strongly suggests that one population occupies both lakes, the effect of the jaw tag, if any, on movement has not been determined. Supplementary checks on the nature of the population in the two lakes have been made by comparing the rate of growth, the coefficient of condition, and the age-class structure of the population.

Rates of growth of 1,608 fish² taken from the spawning runs in both lakes during the spring of 1951 were compared. Approximately equal numbers of fish from Mud Creek in the lower lake and from the Tamarack River in the upper lake were sampled on the same days during the period of May 1 to May 6. All fish were taken in pound nets set

TABLE 3.—Age-composition of walleyes taken from the spawning runs in Lower Red Lake (Blackduck River) and Upper Red Lake (Tamarack River) in 1951; and from commercial catch in 1949, expressed as percentage of total number.

Age ¹ group	Lower Red Lake			Upper Red Lake		
	Spawning run—1951		Commercial —1949	Spawning run—1951		Commercial —1949
	Female	Male		Female	Male	
III.....	.....	6.0	1.6	.....	6.6	1.9
IV.....	5.2	65.5	21.0	5.1	67.2	37.4
V.....	13.5	12.8	44.1	25.1	13.7	44.1
VI.....	42.8	8.5	23.6	48.2	8.6	13.2
VII.....	23.1	4.8	7.5	15.4	2.6	3.0
VIII.....	8.3	1.7	1.4	3.5	0.7	0.5
IX.....	6.1	1.0	0.5	1.6	0.3	.....
X.....	0.9	.....	0.14	0.6	.....	.....
XI.....	.....	.....	.....	0.3	.....	.....
Total fish.	229	970	733	311	1,586	372

¹Number of annuli.

to catch walleyes for spawn-taking operations. There were slight differences in calculated length at each annulus between the samples from the two lakes but these differences appeared to be random. Statistical check on the differences between the means showed them to be far from significant. The importance of this similarity in growth lies in the fact that such close agreement would not be expected if the populations were distinct. Much lower fishing pressure in the upper lake would presumably make a denser population and slower growth rate in that lake. Analysis of catch rates of walleyes by commercial fishermen in both lakes showed that there are no consistent differences in rate of take. This similarity suggests a similar density of population in both lakes which would not be expected if their populations were separate.

²Details of growth-rate comparisons will be included in a later paper of this series.

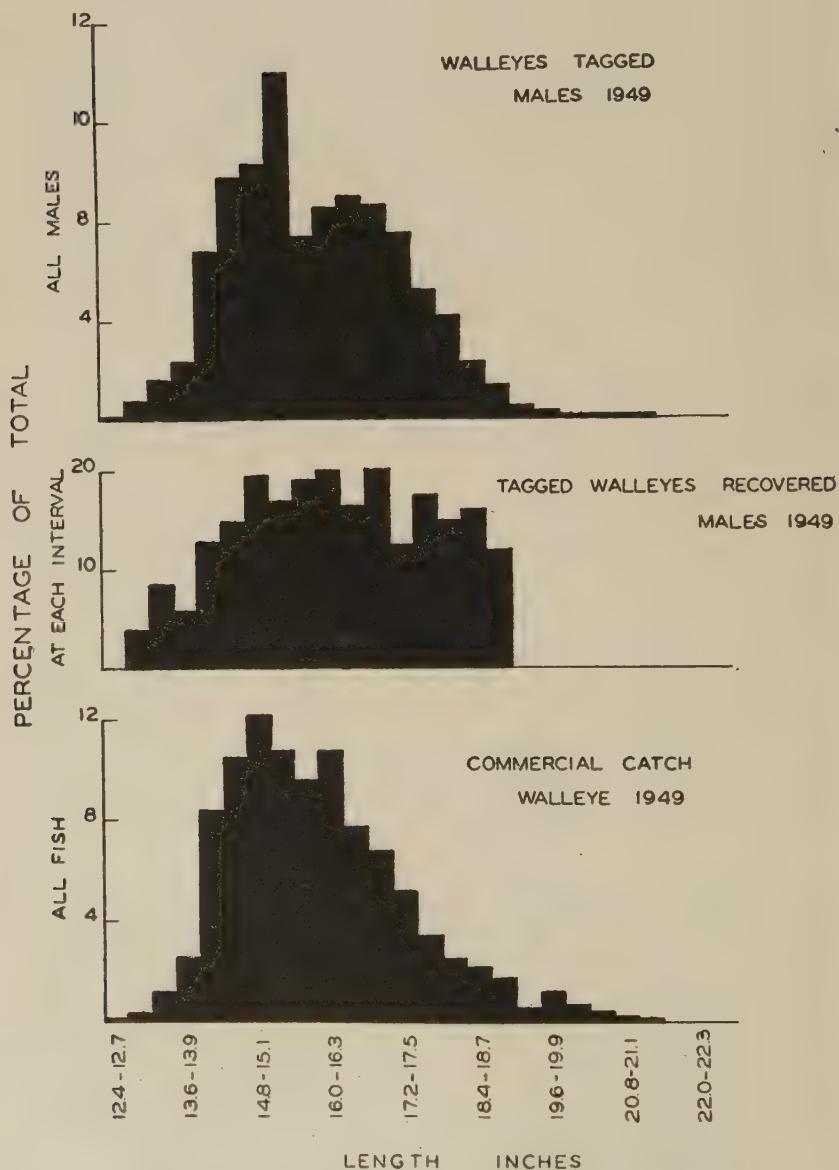


FIGURE 2.—Percentage of male walleyes marked in succeeding 0.4-inch intervals, percentage of marked fish returned in each interval, and percentage of all commercially caught fish in each interval—1949.

Comparison of populations on the basis of age-composition of the spawning run and of the commercial catch shows a tendency for younger age groups to be more abundant in the upper lake than in the lower lake (Table 3). Such a condition would hardly be expected in view of the light fishing pressure in the upper lake. It suggests a situation similar to that described by Paul H. Eschmeyer (1950) in Hardy Pond, Michigan, where in spite of light exploitation, growth was normal and fish were predominantly of younger age groups. He stated that movement downstream was the probable explanation.

A further check on the similarity of the populations was made by comparing the condition factor (K)³ in fish taken from the two lakes. For this comparison 248 fish ranging in total length from 10.0 inches to 16.5 inches were taken from each lake between July 13 and 19, 1949. Care was taken to have the various size intervals similarly represented from each lake. The mean K value of the lower lake fish was 1.59 and of the upper lake fish was 1.57. Differences between fish from the two lakes at each succeeding 0.5-inch intervals were considered to be random.

Examination of the size distribution of marked Red Lake fish which migrated to the other lake with that of fish which remained in the lake where they were tagged, together with the age composition noted above, makes it appear that there is a continual drift of larger fish from the upper lake to the lower lake. Significance tests on the differences in size between migrating and non-migrating fish did not confirm this assumption. This lack of confirmation may have resulted from the relatively small samples and the fact that the majority of fish marked in the upper lake were below the size range where differential movement might be expected.

SIZE DISTRIBUTION OF MARKED FISH IN THE COMMERCIAL CATCH

Since the spawning runs presumably represent the mature population in the lake, the rate of return of these fish in the commercial catch should provide a measure of the relative fishing load on various sizes. Analysis of the commercial catch for 3 years shows that the sizes most heavily exploited are between 13.6 and 16.7 inches, total length. During the years of observation approximately 75 percent of the entire catch lay within these size limits (Table 4). The highest percentage returns of marked fish lay within the range of 14.0 to 20.3 inches total length. Beyond this range the percentage of recapture of marked fish decreased.

If the samples considered here are typical, males become fully available to the commercial fishery at 14.0 to 14.3 inches or during the

³English measurements were converted to metric notations and K factor was calculated by the formula $K = \frac{W \cdot 10^5}{L^3}$, where W equals weight in grams and L equals standard length in millimeters.

TABLE 4.—Length-frequency of marked walleyes, percentage of marked males and females returned in the commercial catch of the season of tagging and the percentage of commercial catch in each length frequency—1949, 1950, 1951 seasons. The percentage distributions of commercial catch in 1949, 1950, and 1951 were based on measurement of 1,349, 4,451, and 14,503 fish respectively.

Length interval (inches)	1949				1950				1951			
	Number marked		Percentage returned		Percentage commercial catch	Number marked		Percentage returned		Percentage commercial catch	Number marked	
	Male	Female	Male	Female		Male	Female	Male	Female		Male	Female
12.0—12.3	.....	.....	20.0	.....	0.1	33	.....	0.0	.....	0.1	85	.....
12.4—12.7	.....	.....	.....	.....	0.2	85	.....	1.9	.....	0.4	85	.....
12.8—13.1	5	.....	4.0	.....	0.4	164	.....	0.6	.....	1.6	208	.....
13.2—13.5	25	.....	8.6	.....	1.3	210	1	1.0	.....	3.5	376	.....
13.6—13.9	58	.....	6.2	.....	2.7	392	1	1.6	.....	6.4	412	.....
14.0—14.3	80	.....	13.3	.....	8.5	204	1	5.4	.....	10.3	445	.....
14.4—14.7	295	.....	14.9	.....	10.5	219	1	4.6	.....	11.6	308	.....
14.8—15.1	309	.....	19.5	.....	12.2	160	2	8.1	.....	10.9	216	.....
15.2—15.5	344	.....	33.3	.....	10.1	155	6	9.0	.....	9.4	141	.....
15.6—15.9	476	.....	18.9	.....	9.6	106	9	7.6	.....	9.3	101	.....
16.0—16.3	249	.....	37.5	.....	11.0	88	12	11.4	.....	8.3	67	.....
16.4—16.7	286	.....	19.8	.....	7.9	70	9	1.4	.....	6.4	40	.....
16.8—17.1	302	.....	16.6	.....	6.9	45	15	8.9	.....	5.3	35	.....
17.2—17.5	289	.....	34	.....	5.3	30	18	3.3	.....	4.6	32	.....
17.6—17.9	252	.....	19.7	.....	3.6	30	18	4.5	.....	3.3	22	.....
18.0—18.3	176	.....	17.6	.....	2.7	22	11	11.8	.....	2.9	13	.....
18.4—18.7	141	.....	10.3	.....	2.3	17	7	0.0	.....	2.3	12	.....
18.8—19.1	68	.....	16.2	.....	1.8	10	8	0.0	.....	0.7	35	.....
19.2—19.5	50	.....	12.5	.....	0.6	9	11	1.1	.....	0.9	23	.....
19.6—19.9	17	.....	12.0	.....	0.6	7	12	14.3	.....	0.0	34	.....
20.0—20.3	9	.....	0.0	.....	1.3	.....	5	0.0	.....	0.7	26	.....
20.4—20.7	8	.....	37.5	.....	0.6	2	6	0.0	.....	0.8	8	.....
20.8—21.1	2	.....	50.0	.....	0.4	.....	2	0.0	.....	0.5	17	.....
21.2—21.5	2	.....	0.0	.....	0.2	.....	1	0.0	.....	0.5	10	.....
21.6—21.9	1	.....	0.0	.....	0.1	.....	3	0.3	.....	0.3	6	.....
22.0—22.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
22.4—22.7	.....	.....	12.5	.....	.....	.....	.....	.....	.....	.....	.....	.....
22.8—23.1	.....	.....	50.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
23.2—23.5	.....	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
23.6—23.9	.....	.....	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....
24.0—24.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24.4—24.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24.8—25.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24.8—26.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	3,374	1,298	.....	.....	.....	1,839 ¹	145	.....	.....	.....	2,525 ²	519

¹11 fish included were between 10.8—11.9 inches.

²4 fish included were between 11.6—11.9 inches.

³0.06 percent of fish (3) were between 8.8—11.9 inches and 0.14 percent (7 fish) were between 22.4—26.8 inches.

fifth growing season (age-group IV, 12.9 inches; age-group V, 14.4 inches).⁴ The majority of males are mature in the spring following the fifth season of growth (Tables 3 and 4, Figure 2). Females become available at the same size and during the fifth growing season (age-group IV, 13.1 inches; age-group V, 15.2 inches; age-group VI, 16.6 inches).⁴ The majority of females, however, do not become mature until the spring following the sixth growing season (Tables 3 and 4, Figure 3). It therefore appears that the great majority of females are subject to 1 year of fishing prior to the attainment of maturity whereas only a small minority of the males are subject to fishing before they are mature. This year of exploitation of immature females may account in part for the large discrepancy in the sex ratio which appears to be typical of the spawning runs. The effects of this reduction in female spawning population may be partly overcome by the fact that the large females are less vulnerable to the nets.

EFFECT OF TAGS ON FISH

It has been shown in many studies that jaw tags may inhibit the growth of fish and there are numerous reports that tagged fish are in poor condition when captured. In the present study it was not possible to examine a large percentage of the fish at the time of recapture. However, in those examined during the spawning season and the commercial fishing season, growth was less than would be expected from the average growth rate of the population. Many of the fish failed to form any annuli in 2 years after release and growth was negligible. Maximum growth in 3 years was 2.4 inches in a female which was 21.1 inches long at the time of marking. In general males of all sizes grew more than females although the sample is too small for definite conclusions. The condition of recaptured fish did not appear different from that of other commercial fish taken at the same time and in only a few individuals was there any appreciable degree of irritation around the mouth.

CONCLUSION

Several generalizations which have fundamental significance for the management of the fishery may be derived from the data presented above. It is apparent that an appreciable number of fish move from one lake to the other following the spawning season. Comparison of growth rates and condition factors of fish from the two lakes shows no significant difference. Observed differences in age and size composition may be explainable in terms of movement of larger fish from the upper to the lower lake although it has not been possible to measure satisfactorily this differential movement. Because fishing pressure is much lighter in the upper lake, a denser population, a greater predominance of older fish, and slower growth rate might be expected.

⁴Average calculated length.

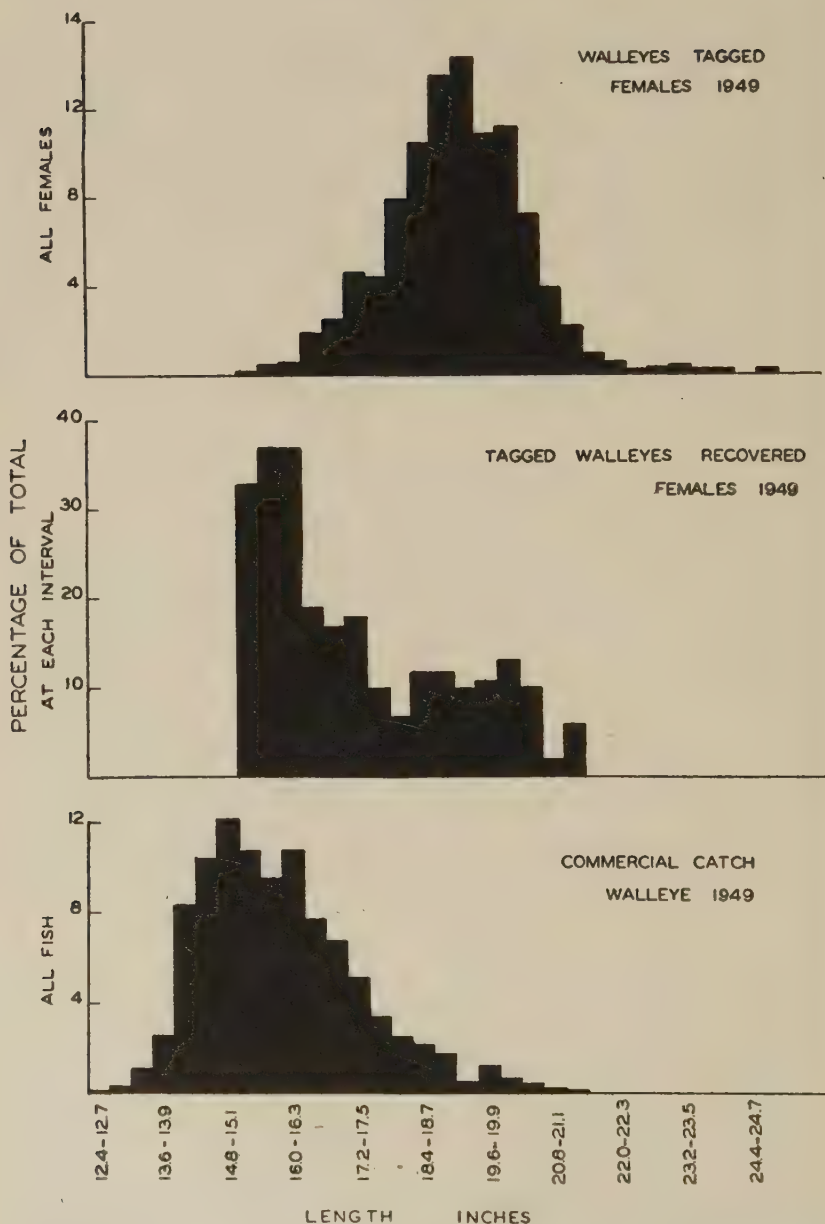


FIGURE 3.—Percentage of female walleyes marked in succeeding 0.4-inch intervals, percentage of marked fish returned in each interval, and percentage of all commercially caught fish in each interval—1949.

However, the population appears to be no more dense, younger fish predominate, and growth rate and condition factors are the same in both lakes. It is therefore concluded that for the purposes of management the population of the two lakes should be treated as homogeneous. Further evidence of general mixing of the various elements in the stock comes from the fact that individual fish move considerable distances soon after the spawning period. Return to the spawning stream in subsequent years appears to be more frequent than movement to other streams but the existence of any true homing instinct cannot be shown on the basis of available information.

Return of marked fish in the commercial catch and comparison of returns with the original marked sample indicate that the great majority of mature males are fully available to the 3½-inch commercial nets. Difference between sexes in average age at maturity makes most females available to the nets 1 year prior to attainment of sexual maturity. Three years of observations also show that many females exceed the size of maximum availability to the gear and therefore in later years of life are subject to a lighter fishing pressure than is exerted on younger groups.

ACKNOWLEDGMENTS

The authors wish to thank: the graduate students in fisheries management and the hatchery personnel of the State and the Red Lake Fishery Association who assisted in the marking operations; W. Ray Kane, David O'Rear, and George Pemberton of the Fishery Association staff, who very materially aided in the return of tags; the superintendent and personnel of the Red Lake Indian Agency; the commercial fishermen whose cooperation throughout the project made the study possible; and the research assistants who aided in laboratory analysis.

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A COMPARISON OF THE ADMINISTRATIVE BASIS FOR FISH MANAGEMENT OF RIVERS IN SCANDINAVIA, GREAT BRITAIN, AND THE UNITED STATES

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ABSTRACT

The philosophy and actual basis for fish management in Europe, the British Isles, Canada, and the United States are compared. The problems of multiple ownership of a fishery are discussed. It is concluded that the full possibilities for fish production can only be realized through administration by a central organization representing all of the owners of a watershed. The need is stressed for united group ownership to insure proper consideration of the fisheries along with agricultural and industrial demands. Examples are cited from various countries to illustrate the need for such administration.

First of all I would like to emphasize the fundamental principle that the basis for all efficient fish culture in a river system is the control of the *whole* area in order that all production possibilities may be fully utilized.

I am sure that it will suffice here to mention that obstructions such as hydro-electric dams, water diversions, agricultural operations, pollution, and improper fishing, are all factors more or less detrimental to fish production, and particularly so if migratory fish exist in the area in question; and it is probably true to say that a larger area is always affected than where these factors actually operate.

First we must consider legal rights to the use of fresh water for fishing. In respect to this, the old world is quite different from the new. In Europe it is chiefly the landowner who owns the fishing rights, and this right is held either individually, or collectively by a number of people possessing common rights, as for instance all the natives of a village. In the British Isles, unless laid down by special Act of Parliament or Ancient Charter, the landowner has the exclusive fishing rights to the water on his land, except in tidal waters which are generally vested in the Crown.

In the new world the right to fish is also generally connected with the ownership of the land except in the larger, navigable waters. In certain states, notably Michigan, the courts have upheld the right of the public to fish even small rivers if they have been used for the transport of logs, providing that access can be gained to such streams without trespass. In many parts of Canada and the United States extensive public ownership of the land insures access to fishing waters which may be fished by all upon the payment of a modest license fee.

In Sweden, the right to fish belongs to the landowner, but this usually means that the right is used collectively by a group of people, for instance a village or even a larger community. This custom is very old and dates back to the beginning of our history when everybody who owned land was able to have his share of the fishing. However, as the population increased, particularly in agricultural and industrial areas, individual interest in fishing decreased. With so many people taking toll of the fish and with pollution, as well as other uses of the rivers, becoming detrimental to fish production, the fisheries became so depleted that they ceased to be of any importance in the daily lives of the people. Perhaps it should be mentioned here that on a comparatively small river in Sweden (100 miles in length for example) up to twenty thousand people may have fishing rights.

To divide is to rule, and with this horde of owners, each possessing an insignificant area and consequently lacking in personal interest, it became progressively easier for industrial and other interests to utilize rivers, to the detriment of the fisheries, with little or no opposition. This state of affairs in many instances has resulted in the utter depletion of the Swedish fresh-water fisheries.

In Sweden we have recently come to believe that this situation should be changed. At present there is a possibility of uniting riparian interests through the formation of fishing associations which will have the power to make and enforce minor regulations for the benefit of the fisheries. It should be remembered, however, that in no case do any of these associations administer all the fisheries in the whole of a given drainage area.

In Norway practically the same conditions prevail, although collective ownership of fishing is not so pronounced. In Denmark the fishing rights usually belong only to the owner of the adjacent land, a system apparently creating a greater interest. This interest is reflected in the comparatively larger fish production of that country.

In all Scandinavian countries there is no central body responsible for the fisheries in the whole of any given drainage area.

On the other hand, in the British Isles, we find quite a different picture. The Fishery Act of 1861 made provision for the formation of Fishery Boards, consisting of riparian owners, representatives of the net fishermen, license holders, and county and county-borough representatives. In a few years after 1861 every important river system in England and Wales had its own Fishery Board which was sometimes called Board of Conservators. These boards, subject to the approval of the Ministry of Agriculture and Fisheries, were given power to make and enforce various regulations for the benefit of the fisheries. Limitation of net fishing, abolition of fixed engines, installation of fish passes on many hitherto insurmountable weirs, and good work done

by the water bailiffs in suppressing some of the more destructive forms of poaching were some of the factors contributory to the recovery of the rivers.

In the British Isles, as already mentioned, the right to fish belongs to the landowner exclusively, and not infrequently the river with its fishing is more valuable than the large parcel of land of which it forms a part. The fishing is often leased or sold separately from the land.

The formation of Fishery Boards in the British Isles has been of the utmost importance, for they have represented a power which other interests could not overlook. Fishery interests were united, and not divided as in Scandinavia. The ultimate result of this union is that in the British Isles between 18 and 22 million pounds of salmon are produced annually, while in Sweden, with its much larger area of production, the annual catch of salmon only amounts to between 3 and 7 million pounds.

In my opinion, this reveals one of the basic factors for rehabilitation of our fisheries—the principle that an individual is interested and acts only with so much ownership that he may benefit from the work he does. It seems to me that in the British Fishery Boards this principle has operated correctly, avoiding the drawback that when ownership or benefits are divided among too many people, the reward is too small to be of any consequence to any one of them. It is easy, therefore, to see why initiative and investment are so sadly lacking in some other countries. This condition certainly exists in Sweden. Practically all of our fresh-water fisheries are very little utilized for this reason.

If this is applicable to America, then all is far from well. I am not so conceited as to think that I can give you any advice as to how to manage your waters and fishing rights. American fisheries biology is of a very high standard, and you have that ideal system in which every citizen, no matter what his standing in his community, possesses the right to follow in the footsteps of Izaak Walton and fish when he wants to.

On the other hand, I suppose it cannot be denied that here in the United States, the interests opposed to the development and maintenance of fisheries and angling possibilities, have brought many American rivers to a very low state of production. The woods and the waters are the heritage of the common man; the amenities and health-giving relaxation associated with fishing in pure and well-stocked rivers are of incalculable value, and cannot be estimated in terms of dollars. It therefore behooves every good citizen to support every measure which will help in the fight against the encroaching interests that tend to deprive the ordinary man of his inherited right.

A good example of what it would mean to the United States if some of the rivers were utilized to the fullest extent, is in Maine where the Atlantic salmon is practically extinct. A few years ago I looked at

the Penobscot River in Maine and was informed that the production of Atlantic salmon in that river was in the neighborhood of a few thousand pounds a year.

If we compare this with the River Tay in Scotland, for example, which is a smaller river and in my opinion has no better potentialities, we find that the Tay has an average production of about one million pounds a year, against a few thousand pounds in the Penobscot. The same thing applies to every other river in Maine.

Another example, this time from England, may be of some interest. I refer to the Chester Dee which has its source in Bala Lake, 104 miles by river from the sea and exhibits an extreme dry weather flow of about 70 million gallons a day—a very small river indeed. This river takes care of the effluents from more than 70 industries and communities, which include sewage from a population of 300,000 people. Three very large industries are found here—a chemical factory, a rayon plant, and steel works, which altogether employ more than 14,000 workers. In spite of this industrial development the Chester Dee is a productive salmon river. As I think you will appreciate, it would be a far sadder story were it not for the powers of the River Dee Fishery Board who require standards of effluent purification which render harmful industrial wastes more or less innocuous to stream life.

The River Dee is an interesting example of what can be done to safeguard a river's natural production in a heavily industrialized area. At the turn of the century through over-netting in tidal and inland waters, absence of adequate fish passes, and extensive poaching, the annual production of salmon amounted to only three or four thousand pounds a year. But thanks to the energetic action of the Fishery Board in passing beneficial bye-laws curtailing netting in tidal reaches, prohibiting netting altogether in inland waters, enforcing the regulations against pollution, and detecting and preventing poaching, the annual average catch of salmon now amounts to about 63,000 pounds a year.

The Fishery Boards operate practically the same in Scotland as in England, although there is a little difference in that they are chiefly concerned with salmon only.

Another thing of more than passing interest in England is an Act of Parliament known as the Rivers Board Act of 1949. The objects of this law are to do away with the old Fishery Boards, Land Drainage Boards, and Joint Pollution Committees, and to provide for the election of River Boards responsible for the fisheries, pollution, and land drainage area of the whole of one or more watersheds or drainage areas. Whether or not this new law will have the effects wished for remains to be seen. Many skeptical voices have been heard expressing the opinion that the fisheries interests will not be able to maintain or enlarge upon their position against the seemingly more powerful interests, for instance of land drainage. Because these other interests will be represented on the River Boards, they may be able to outvote the

fishery interests. And it is not always the majority which is more foresighted and willing to shoulder responsibility when it comes to the maintenance of a natural resource like fishing and clean water. Objects which at the moment are thought to be of more importance will often get priority over water, which may mean that a natural resource will be depleted.

It is very interesting to find that in the British Isles the principle is maintained that every drainage area is a biological unit which should be administered by a central body, in this case the Fishery Board. Every Fishery Board is built upon these principles. The production of fish is something that is quite different from the production of farm stock for instance, since fish live in water which can easily be made uninhabitable by pollution or impassable through obstructions. Pollution affects the fish, not only below the point of pollution, but also in other areas.

These are things we all know, but the ultimate consequences are that a really productive river can probably never be obtained unless the whole river is administered by one central power. I think I can safely say that we in Europe now think that the ideal is to get the fishing interests united as closely as possible so that the individual gets a chance to act for himself, within the limits of some form of *united* group ownership. As far as I can see, an efficient fishery administration in Europe will not be possible until we get local interests united in such a way that they themselves all together are responsible for the production and maintenance of the fisheries and enjoy the benefits thereof. Unless they receive the benefits nothing will be done. Leaving this to the small staff employed by the state, functioning mainly as research workers, will certainly not advance it.

I suppose we can all agree that our work is to find ways and means of producing more fish. The biological problems are of the utmost importance and work on them has really only just started, but these problems represent only one side of the picture. The uniting of fishery interests, so that they can stand up for the rights of fisheries, represents the other side.

ECOLOGICAL EFFECTS OF WINTER CONDITIONS ON TROUT AND TROUT FOODS IN CONVICT CREEK, CALIFORNIA, 1951

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ABSTRACT

In 1951, winter studies were conducted at the Convict Creek Experiment Station of the U. S. Fish and Wildlife Service located at 7,200 feet elevation in the Sierra Nevada Mountains near Bishop, California. These were designed to extend knowledge of winter conditions in stream environments and to bring to light problems requiring further investigation at this season. Common stream survey methods were employed to procure and analyze data.

Snowfall was meager at Convict Creek in 1951, but freezing temperatures induced extensive ice formations. Surface ice immobilized screens and other objects protruding from the water, yet provided the trout with abundant shelter. Frazil and anchor ice had a more pronounced effect on stream life and water temperatures than surface ice. When subsurface ice was present, the water was at or very close to the freezing point, regardless of weather conditions or time of day. Anchor ice formed and dispersed in a daily cycle that caused wide fluctuations in stream flow. Minimum water flow at night often left secondary channels empty, while morning peak flows scoured the stream with ice fragments, washing loose debris and bottom fauna. Trout were active in the freezing water and fed regularly throughout the winter. Trout were caught on bait when the water was 32° F.

Large numbers of aquatic organisms were dislodged by fluctuating flows and became available as food for trout. Clear indications were obtained of high seasonal fluctuations in the abundance of bottom organisms. Adult stoneflies and dipterans emerged on warm days during the winter.

A comparison between the numbers of stream bottom organisms present, drift foods, and foods consumed by trout, gave a positive correlation. In cold weather, trout consumed large numbers of mayfly and stonefly nymphs, while dipterans predominated in trout stomachs over the entire winter. Rainbow and brown trout of similar lengths and stomach volumes differed in the number of organisms eaten by each in that rainbow trout ingested larger quantities of small organisms than did brown trout.

Wild trout suffered an initial mortality in early January that was caused by heavy subsurface ice which blocked stream flow into side-channels. Very few dead trout were found after this occurrence. The over-winter survival of marked trout approximated 50 percent in 1950-51.

INTRODUCTION

Studies of winter conditions in trout waters have been neglected in many areas. As was pointed out by Hubbs and Trautman (1935), inland fishery research has usually been limited to summer months because working conditions are better and there seldom are both living and laboratory facilities available and easily accessible for winter investigations. The Fish and Wildlife Service of the U. S. Department of the Interior has such facilities at its Convict Creek Experiment Station in Eastern California. In cooperation with the University of California it conducted a study of winter conditions over the period from November, 1950, through April, 1951. The main effort was directed toward discovering the effect on trout of low water temperatures, ice formation and dispersal, snow, and other ecological factors.

The principal species of fish in the area of Convict Creek where these studies were made are brown trout, *Salmo trutta* Linnaeus, and rainbow trout, *Salmo gairdneri* Richardson. Brown trout are by far the more abundant. Only rarely is an eastern brook trout, *Salvelinus fontinalis* (Mitchill), taken. Suckers and cyprinids are common in lower Convict Creek and in Lake Crowley, into which it flows some 3 miles below the Convict Creek Station.

THE STUDY AREA

The Convict Creek Station is located on the eastern escarpment of the Sierra Nevada Mountains in Mono County, California, at an elevation of 7,200 feet. Convict Creek rises in snow-fed lakes near the crest of the Sierras, plunges precipitously down a canyon, dropping 2,300 feet into Convict Lake. From here, the stream drops about 400 feet in 2 miles to the experimental area. Convict Creek below the lake flows rapidly through a boulder-strewn, tree-bordered canyon for about 1 mile, after which it enters flat meadow-like areas bordered on both sides by wide sagebrush flats. There the water course averages about 10 feet in width and has a bed of rubble, gravel, and sand. Natural spawning areas of fine gravel are found at frequent intervals. The pines, cottonwoods, birch, and alders that border the stream in the canyon are replaced by willows in the meadow. There is little aquatic vegetation except for small patches of *Ranunculus*. Under-cut banks, holes, submerged logs and debris provide excellent natural cover.

The experimental stream system now in use consists of four, one-quarter-mile channels. The full flow of the stream is divided in half, each half then flowing through two sections which are screened at their upper and lower ends. A flood control structure is provided above the area to divert excess flood waters around the four experimental stream sections. The winter studies described in this report were made principally within the areas encompassed by the Convict Creek Station, though some of the observations were made in adjacent waters both above and below the station area proper.

Winters at Convict Creek are characterized by heavy snowfalls, high winds, and low temperatures. Snow usually averages 2 to 4 feet deep on the level and wind-borne snow, blown from adjacent high ridges, often bridges the entire width of the creek.

The winter of 1950-51 was comparatively mild in that less than 2 feet of snow fell during the period of study, and low temperatures alternated with periods of mild weather. Nights were generally cold and clear while days were bright and windy. Only two periods of extreme cold weather occurred in 1951. These were severe enough to cause heavy ice formations in the stream and permitted observations of their effects on stream ecology.

METHODS AND EQUIPMENT

The techniques and equipment employed were those generally used in stream survey work. Stream bottom organisms were collected with the Surber square-foot sampler. This device, with a coarse screen fender, was used as a stationary net to capture stream drift organisms. It was staked to the bottom of the stream for 15-minute intervals at various times of day and under varying stream conditions.

Trout for stomach analyses were taken by seine, trap, and angling. Water flow records (Table 1) secured from the City of Los Angeles were supplemented by additional flow measurements taken with a White current meter. Continuous air and water temperatures were taken by

TABLE 1.—Mean monthly discharge of Convict Creek from November, 1950, through April, 1951.

Month	Stream flow cubic feet per second		
	Mean	Maximum ¹	Minimum ¹
November.....	18.9	44.3	6.5
December.....	23.0	35.1	13.7
January.....	10.6	13.7	1.3
February.....	10.4	13.9	9.2
March.....	8.3	10.8	7.2
April.....	11.2	15.4	7.7

¹Refers to extreme daily means occurring within the month¹

means of a Taylor recording thermometer ranging from 0°F. to 100 F. and graduated in 1° intervals. Temperatures taken from these charts (Table 2) were read to the nearest 0.5°F. Supplementary water-temperature measurements were made with a Foxborough resistance thermometer, the vernier of which was graduated in half degrees and interpolated to the nearest 0.1°F. Water temperatures reported here were taken with the resistance thermometer, unless otherwise noted.

TABLE 2.—*Mean monthly maximum and minimum air and water temperatures in Fahrenheit and mean times of occurrence at Convict Creek, California, January 1 through March 31, 1951.*¹

Month	Air temperatures			Water temperatures				
	Monthly mean		Monthly mean		Monthly mean		Minimum water temperatures ²	
	Maximum	Time	Minimum	Time	Maximum	Time	Minimum	Total hours
January.....	44.5	2:00 P.M.	16.3	4:15 A.M.	37.9	3:00 P.M.	9:45 P.M.—1:30 P.M.	222
February.....	47.5	2:30 P.M.	18.1	4:00 A.M.	40.2	3:15 P.M.	12:15 A.M.—11:15 A.M.	166
March.....	53.2	2:45 P.M.	19.9	3:30 A.M.	44.5	3:30 P.M.	1:00 A.M.—10:00 A.M.	117

¹Compiled from thermograph charts, Taylor recording thermometer.

²Temperatures of 32° F. or lower.

ICE FORMATION IN STREAM

Three types of ice may appear in streams in boreal climates. Surface or sheet ice which forms over the surface of the water is most common. Frazil and anchor ice, two less known types, form within the water (subsurface). Frazil is an extremely soft, grey ice composed of fine spicules and may appear as feathery wisps undulating in the current, as clumps at the surface of the water, or as a stationary, slushy mass occupying the entire depth of the water. Anchor ice appears as a grey, translucent coat over immovable objects in the stream bed. It is composed of crystals larger than those of frazil, which makes it more granular and gives it some rigidity. Both subsurface ices, if free from particulate foreign matter, appear brilliantly white when removed to the atmosphere.

Surface ice formations grow from the edge toward the center of the stream until a complete layer is formed. It then thickens by crystallization on the underside as heat is transferred upward through the ice. In Convict Creek, sheet ice formed over the surface of slow pools and shelf-like along stream banks in riffle areas, reaching a thickness of 8 inches in some localities. Light accumulations of snow rendered it opaque.

Although surface ice may form when subsurface waters are well above freezing, subsurface ice never appears until the whole water mass reaches the freezing point. The time at which the stream reaches its lowest temperature coincides with the first appearance of subsurface ice. Barnes (1906) recorded the minimum temperature of the St. Lawrence River at -0.0068°C . (31.988°F .). In an experiment with a container of water that was agitated as it was cooled, Barnes also found the lowest water temperature was -0.014°C . (31.975°F .) at the time ice first appeared. Convict Creek waters showed a minimum temperature slightly below 32°F . Within minutes, particles of ice became abundant and the temperature increased slightly but retained a position between the minimum and 32°F . In Table 2, it will be noted that water temperatures of 32.0°F . or lower existed for a total of 222 hours in January, 166 hours in February, and 117 hours in March.

Both forms of subsurface ice may result from tiny, clear, colloidal particles which resemble ice but lack its true crystalline form. Colloidal discs formed quickly and extensively in Convict Creek on clear, cold nights when excessive terrestrial heat radiation lowered the stream temperature to freezing. They were secured from the stream by means of a cheesecloth strainer and measured up to 3 millimeters in diameter.

Frazil ice forms throughout the water as minute, irregular crystals, the extent of the formation being largely dependent upon the agitation of the water. Turbulence may be produced both by swift currents in steep riffles and by wave action from strong winds. Frazil ice was also formed from the crystalline growth of colloidal particles and from super-cooled snow falling into water which was at or below the freezing point.

The volume of frazil formed on a cold windy day may be immense, for Barnes (1928) reports accumulations up to 80 feet in thickness beneath surface ice on the St. Lawrence River. Large quantities of frazil appeared in Convict Creek on only one day during this study.

Terrestrial radiation is commonly accepted as the cause of anchor ice formation. At Convict Creek anchor ice formed only at night and apparently never under an overcast sky or opaque layer of surface ice, since these tended to reflect the heat being radiated from the earth below. The cloud-like masses of anchor ice that formed nightly made up the bulk of the ice. Anchor ice was observed to form soon after the appearance of colloidal discs: first, on the rubble at the downstream ends of pools; second, on the rough substrate in riffles; and lastly, at the bottom of pools. The amount of this ice formed in any one night was determined by depth, turbulence, and rate of heat radiation from the water. Most of the colloidal particles, as well as any frazil crystals present, adhered to the coarse anchor ice, grew, and became part of that formation.

EFFECTS OF STREAM ICE

The effects of ice formation on stream life are both beneficial and harmful (Hazzard, 1941). Needham (1938) notes that snow-bridges completely covering small streams afford insulation against both cold and predators. Later, Smith (1947), in similar work on Convict Creek, found that wind-drifted snow combined with stream ice blocked an experimental stream channel and caused a 4-hour cessation of flow and a consequent draining of water from the channel into the substrate.

Sheet and shelf ice offer excellent shelter to trout along otherwise open stretches of stream. Brown and rainbow trout in Convict Creek took advantage of the increased cover. They could usually be frightened from these retreats by breaking loose a section of shelf ice. Surface ice greatly impeded observations and recovery of trout. It also caused much disturbance to the stream banks and bottom when water surges broke it loose. At such times, large masses of ice with embedded twigs, leaves, and other vegetation were swept over shallow riffles in heaps of tumbling cakes.

Subsurface ice, being far more abundant than surface ice, had a much greater effect. Frazil caused extensive damage to Convict Creek on January 19. In the early morning hours, winds of extreme velocity (estimated at 80 miles per hour) blew in snow from higher elevations and so churned the creek surface that the water became filled with fibril slush. The flowing water was forced into small channels within the slush and flooded out of the main stream at every turn where the banks were low. Moving masses of soft ice carried off two foot-bridges and caused other damage. The stream was carefully inspected during and after the ice dispersed, but no evidence of harm to trout was found.

Anchor-ice formations on rocks at the bases of pools raised the effective height of the pool dams and impounded considerable quantities of water. Encrustations of ice blocked the flow of water into side-channels and turned screens into watertight dams. The result was a gradual decrease in volume of flow. Solar radiation at dawn halted further growth of anchor ice and soon the radiant heat loosened the weak bond between anchor ice and substrate. Clumps of anchor ice broke free, and moved downstream with the current. Impounded water was liberated as the ice breakup progressed and the increasing flow scoured the stream,

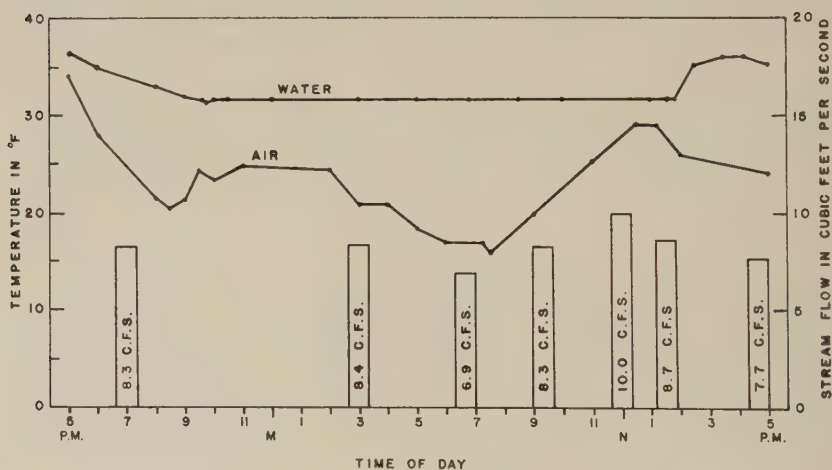


FIGURE 1.—Air and water temperatures and stream discharges recorded in Convict Creek, California, over a 24-hour period on February 25 and 26, 1951.

breaking loose additional quantities of ice and debris. At noon, February 23, a flow of 16.4 cubic feet per second was recorded in the area. The mean flow for this date, according to the discharge record, was 9.8 cubic feet per second. The flow, therefore, must have increased more than double between the early morning minimum and the measured maximum at noon. More typical were daily flows that varied by 4 cubic feet per second (Figure 1). The surge of water disturbed the stream bed enough to carry off many aquatic organisms. This dislodgement proved to be an advantage to trout by making riffle-dwelling insects such as mayflies, stoneflies, and caddiceflies readily available.

The presence of subsurface ice kept water temperatures at a 32°F. minimum (Table 2), but as soon as this ice was gone, water temperatures rose regardless of air temperatures or intensity of the sun. Reports of anchor ice lifting gravel, stones, and even large rocks are recorded by Barnes (1906), but these instances occurred in large waterways where

suitable conditions enabled the ice to remain attached for several days and become quite thick. Convict Creek cleared daily and, upon one occasion, floating anchor ice had fine gravel imbedded in its base. Seining trout in ice-laden waters was impossible because a slight contact would dislodge the loose clinging ice and fill the net with jagged spicules.

DAILY TEMPERATURE CYCLE

A typical 24-hour period of winter stream and weather conditions is illustrated by data collected February 25 and 26, and presented in Figure 1. Air and water temperatures dropped steadily in the afternoon and evening of February 25. The air reached 32°F. at 6 P.M. and remained slightly below this point during the succeeding 2 days. At 9:45 P.M., the water momentarily dipped to its minimum temperature and colloidal particles appeared. Within 10 minutes, the concentration of these discs was so great that they could be seen within the water. Fine filaments of anchor ice began to form on a rock under observation at 10 P.M. This formation grew visibly for several seconds and, within a minute, appeared on many adjacent rocks. Growth then progressed less noticeably, to form a mat over the stream bed. Colloidal discs disappeared from the water. By 10:30 P.M., anchor ice had become 2 inches thick, and further growth continued until 11 P.M., when a cloud cover moved over the sky. The growth of anchor ice halted temporarily and stream flow, which had been decreasing by impoundment, began to rise slightly. A fine, light snow fell intermittently until 3:00 A.M., when the cloud layer broke up. The snow crystals that fell into the stream formed filmy masses of frazil that trailed downstream. As soon as the cloud cover scattered, anchor ice resumed its growth, air temperatures dropped, and stream flow decreased. These conditions prevailed until sunrise, when the anchor ice had reached a thickness of 7 inches.

Little change was observed between sunrise (6:45 A.M.) and 8:30 A.M., except a slight loosening of anchor ice from the stream bottom and a visible increase in stream flow. The real breakup of anchor ice commenced at 8:30 A.M., causing a rapid increase in volume of flow. At this time, many trout appeared in the stream to feed on the food being carried downstream. Stream flow leveled off shortly after noon. All anchor ice became free from the stream bed by 1:30 P.M. and stream flow then dropped noticeably. After floating clumps of subsurface ice disappeared at 1:50 P.M., the water temperature rose suddenly to 36°F. at 3:30 P.M. After this time trout ceased to feed and both temperatures and flows slowly decreased to 5:00 P.M., thus completing the 24-hour cycle.

ACTIVITY OF TROUT

It is generally assumed that trout are less active during the winter months than in the warmer seasons. Excluding migrations, this condition was found untrue, since trout in Convict Creek were quite active in spite of cold water temperatures. Most of the time, the fish remained

under shelf ice, cutbanks, and among willow roots and brush. As the sun took effect upon subsurface ice, trout suddenly appeared in the open stream. Throughout the day, especially as temperatures rose, the fish could easily be observed. In late afternoon, trout seemed to disappear as the temperatures dropped. Very few trout were seen at night, although several fish kept in a live car were observed at all hours. These fish were far from sluggish at night in the freezing, ice-laden water. Frazil and anchor ice usually had to be cleared away to find the trout, but they deftly avoided capture by hand.

No device was installed to check migrant fish but a careful watch was kept at the screening points on the experimental sections. During fall months, brown trout fingerlings nearly always could be found in the enclosed water between the screens and the flashboards. One warm February day with the water at a monthly peak of 44°F. several fingerling brown trout were observed on the concrete apron of the lower screen structure attempting to enter the experimental sections. No such attempts were observed again until late March, at which time the water temperatures rose above 43°F. Two large brown trout tried to enter the sections in late January and early February during a warm spell of weather.

Some trout normally occupied small side channels during summer and fall. Observations indicate that these trout vacated the side channels in early January, frequented them occasionally on warm winter days, and returned from the main stream to reinhabit the smaller channels in late March.

WINTER FOOD SUPPLIES

Winter is the time of greatest abundance of immature aquatic insects, a matter of considerable importance to trout. Besides the usual forms of aquatic organisms common to Convict Creek, an abundance of aquatic oligochaetes [*Helodrilus tetraedrus* (Savigny)] appeared during the months of study. So numerous were these bristle-worms in certain areas that a handful of coarse sand from the stream bottom yielded a dozen individuals. They formed approximately 10 percent of drift and bottom foods available to trout in the winter of 1951.

The emergence of adult insects was a fairly common event throughout the winter, perhaps because the weather was mild in 1951. On December 29, a hatch of blackflies (Simuliidae) took place. Thereafter, on warm days in latter January, mid February, and most of March, when water temperature was 40°F. or more, some blackflies and many midges (Chironomidae) emerged. Adult stoneflies (genera *Nemoura* and *Capnia*) appeared abundantly in late January and sparingly during the remainder of the winter. Besides these aquatic forms, terrestrial dipterans and lepidopterans were found. Mayfly and microcaddis adults (Hydroptilidae) began emerging in late March.

BOTTOM FOODS

Few quantitative riffle bottom samples have been taken under severe winter conditions. Needham (1938) reports a standing crop of 103 pounds per acre in the Merced River in California in February of 1933. Bottom samples taken from the same riffle in August produced an average of 85 pounds per acre. Both of these figures are based upon four samples. Convict Creek, from a series of five samples taken in February of 1942, indicated an average standing crop of 134 pounds per acre.

It is of interest to compare the amount of bottom foods found in winter with those obtained from summer samples in Convict Creek. Over the 5-year period from 1938 through 1942 inclusive, 225 bottom samples were taken in Convict Creek between May and September. Unpublished data indicate that the 5-year average was 109 pounds per acre and the average, annual summer amounts varied from a low of 68 pounds per acre in 1938 to a maximum of 197 pounds in 1942. While the five winter samples taken in 1942 produced an average of 134 pounds per acre and are far too few in number for any adequate comparison with summer food conditions, nevertheless it is evident that the 134 pounds per acre is well above the average of 109 pounds indicated for the five seasons covered. The reasons for greater abundance of bottom foods in winter must be that few aquatic insects emerge in winter and therefore the bulk of them are present in one stage or another.

A comparison of the food organisms found in 11 bottom samples taken in the winter of 1951 and the 5 samples secured in February, 1942, is presented in Table 3. Mayfly nymphs dominated the 1942 samples forming over 53 percent of the 1,865 animals collected, while in the 1951 series other groups were relatively more numerous. Caddicefly larvae, for instance, contributed over 29 percent. Midge larvae made up over 12 percent of the 1951 samples and 18.8 percent of the 1942 collections. Oligochaetes were much more abundant in 1951 when they totaled 139 or almost 12 percent. In 1942 only 79 of these organisms formed 4.2 percent.

Wide differences in both seasonal and yearly abundance of bottom food are indicated in the above figures. The average number of animals collected per square foot in the 1951 winter samples was 107; that for the five taken in February, 1942, was 373 or over three times as many. As was pointed out above, the 1942 summer series of samples indicated an average of 197 pounds per acre and evidently the winter abundance was reflected over the following summer when the measured crop increased from the winter average of 134 pounds to 197 pounds per acre.

The implications of these findings with respect to stocking policies are obvious. Evidently stream populations are highly unstable and subject to vicissitudes similar to those of land animals and plants. The use of arbitrary stocking tables will, we feel, become a thing of the past or they will have to be modified by the development and application of factors to reduce or increase the numbers of fish to be stocked in relation to variable seasonal or annual conditions and fishing pressure.

DRIFT FOODS

A total of 130 organisms was collected in nine samples. As will be seen in Table 4, caddicefly larvae and dipterans occurred in equal numbers followed by mayfly nymphs, oligochaetes, beetles, and stonefly nymphs, respectively. In terms of weight, oligochaetes contributed over 55 percent, mayfly nymphs, 26.5 percent, with the other groups contributing relatively minor amounts.

TABLE 3.—*A comparison of the number and percentage of riffle bottom organisms from Convict Creek in 1942 and 1951 (11 samples, 1951; 5 samples, 1942).*

Group of organisms	January-March, 1951		February 9, 10, 1942	
	Number & stage ¹	Percentage	Number & stage ¹	Percentage
Ephemeroptera.....	258(n)	21.8	995(n)	53.4
Trichoptera.....	346(l)	29.3	237(l)	12.8
	1(p)		1(p)	
	140(l)		1(a)	
Diptera.....	2(p)	12.4	351(l)	18.8
	5(a)			
Coleoptera.....	151(l)	16.0	162(l)	9.7
	39(a)		18(a)	
Plecoptera.....	37(n)	3.2	10(n)	0.5
	1(a)			
Oligochaeta.....	139	11.7	79	4.2
Miscellaneous.....	67	5.6	11	0.6
Totals.....	1,186		1,865	

¹Abbreviations used: l—larvae, n—nymphs, p—pupae, and a—adult.

The greatest number of drifting foods was always found during periods of peak flow. On one occasion, a set made from 11:10 A.M. to 11:25 A.M. contained a large number of insects, while sets preceding and following it by 15 minutes, gave meager returns. The organisms captured in this manner (Table 4), as might be expected, are generally the smaller ones of weak attachment or poor swimming ability. It is conceivable that larger organisms return to the substrate quickly upon being dislodged, while smaller ones may be carried far in the current.

Trout were observed feeding only during and following peak flows. It was thought that, under these conditions, trout might feed only upon the drifting organisms. Data from bottom samples, drift samples, and trout stomachs taken during such periods are grouped for comparison in Table 5. Here it is evident that there was some correlation between availability and ingestion. Caddiceflies were dominant in the four bottom samples concerned, forming 28.3 percent by number, while this group totaled 41.7 percent of foods eaten by 18 trout and 28.5 percent of all drift foods available. Similarly, mayfly nymphs formed 19.4 percent,

23.8 percent, and 31.8 percent, respectively, of the number of bottom, drift, and ingested foods. Comparing these on a basis of weight (Table 5), little correlation is evident.

STOMACH EXAMINATIONS

A few trout were collected by seine, trap, and angling each week for stomach examinations. Analysis of these data shows a marked difference between the winter food habits of brown and rainbow trout (Table 6). Forty brown trout stomachs contained 578 organisms or 14.5 per fish, while 53 rainbow trout consumed 1,337 organisms or

TABLE 4.—*Number and weight of organisms taken in 9 drift net samples, Convict Creek, California, February 19 through March 8, 1951.*

Group of organisms	Number & life stage ¹	Percentage by number	Weight in grams ²	Percentage by weight
Oligochaeta.....	14 3(l)	10.7	.139	55.8
Coleoptera.....	1(a) 29(l) 5(p)	3.1	.001	0.4
Diptera.....	3(a)	28.5	.020	8.1
Ephemeroptera.....	31(n)	23.8	.066	26.5
Plecoptera.....	3(n)	2.3	.006	2.4
Trichoptera.....	37(l)	28.5	.016	6.4
Miscellaneous.....	4	3.1	.001	0.4
Totals.....	130	.....	.249	.....

¹Abbreviations: l—larvae, n—nymphs, p—pupae, a—adults.

²Weight from alcohol.

25.2 per fish. Yet, the mean stomach volume for all brown trout was 0.29 cubic centimeters, and that for all rainbow trout was 0.28 cubic centimeters. This difference in numbers of organisms consumed is accounted for by the greater percentage of larger organisms in brown trout stomachs. The rainbow trout ingested many small midge and blackfly larvae, while brown trout consumed proportionately more caddicefly larvae.

Over the whole winter period dipterans represented only 12.4 percent of total available bottom organisms (Table 3) but supplied the greatest percentage in numbers of food items eaten (Table 6), both by rainbow (54.9 percent) and brown trout (31.6 percent).

Further analysis indicates a difference in general winter feeding habits as compared to strictly cold water feeding. A comparison of foods ingested in ice-laden water (Table 5) with those taken during the entire winter, December 29 to March 22 (Table 6), denotes a greater cold water consumption of mayflies, stoneflies, and caddiceflies, with more flies (Diptera), beetles, and oligochaetes being ingested during the entire period of study.

A rainbow and a brown trout between 6 and 8 inches long each had two, eyed trout eggs in their stomachs (Tables 5 and 6). This was the only direct evidence of disturbance to spawning beds observed. These fish were taken during extremely cold weather when much anchor

TABLE 5.—Comparison of fish food organisms from 4 stream bottom samples, 9 drift net samples, and 18 trout stomachs,¹ Convict Creek, California, February 19 to March 8, 1951.

Group of organisms	Percentage by number			Percentage by weight ²		
	Bottom foods	Drift foods	Ingested foods	Bottom foods	Drift foods	Ingested foods
Trichoptera.....	28.3	28.5	41.7	12.2	6.4	58.1
Ephemeroptera.....	19.4	23.8	31.8	5.4	26.5	9.4
Diptera.....	14.0	28.5	17.2	8.7	8.1	10.2
Plecoptera.....	3.0	2.3	4.0	11.8	2.4	1.6
Oligochaeta.....	10.7	10.7	2.7	60.6	55.8	9.8
Coleoptera.....	22.0	3.1	1.3	1.2	0.4	1.5
Miscellaneous.....	2.6	3.1	1.3	0.1	0.4	9.4

¹Stomachs from 9 brown and 9 rainbow trout.

²All weights from alcohol.

ice formed at night. The action of ice in disturbing spawning gravels may have freed these eggs in the current. Scarcity of trout eggs in the stomachs suggests that anchor ice in the winter of 1951 caused slight disturbance to naturally spawned brown trout eggs.

Observations and stomach examinations indicate that low water temperatures did not limit the feeding activity of trout in Convict Creek. In over 100 healthy specimens of trout taken, only one rainbow

TABLE 6.—Organisms found in stomachs of 40 brown and 53 rainbow trout, Convict Creek, California, December 29 through March 22, 1951.¹

Group of organisms	Brown trout		Rainbow trout	
	Number ²	Percentage by number	Number ²	Percentage by number
Oligochaeta.....	27	4.7	46	3.4
Coleoptera.....	17(l)	7.4	45(l)	3.9
	26(a)		7(a)	
Diptera.....	143(l)	31.6	712(l)	54.9
	14(p)		12(p)	
	26(a)		10(a)	
Ephemeroptera.....	65(n)	11.6	187(n)	14.1
	2(a)		1(a)	
Plecoptera.....	14(n)	2.8	8(n)	0.8
	2(a)		2(a)	
Trichoptera.....	215(l)	37.2	288(l)	21.5
Miscellaneous.....	27	4.7	19	1.4
Total.....	578		1,337	

¹Brown trout size—range was 8.3 to 20.7 centimeters (total length), with a mean total length of 14.3 cm. Rainbow trout ranged in size from 8.0 to 31.7 centimeters and had a mean total length of 14.5 cm. Total length as used here means length from tip of snout to end of caudal rays.

²Abbreviations used: l—larvae, n—nymphs, p—pupae, a—adults.

and three brown trout had stomachs that contained only a trace of food or none at all. Trout were observed feeding at all water temperatures. On several occasions trout were taken by hook and line (using a single egg or an aquatic bristle worm) in ice-laden water at a temperature of 32°F. Surface feeding was observed whenever aerial insects were present and usually at a water temperature of 35°F. to 42°F. The regularity of trout feeding during periods of low water temperatures raised the question of digestive rates. Hess and Rainwater (1939) reported that brook trout digestion was almost at a standstill in 1.9°C. (35.4°F.) water. A superficial experiment was conducted at Convict Creek by the senior author, in which several trout were force-fed mayfly and stonefly nymphs, and aquatic oligochaetes, then returned to a live car in the creek. Examinations of the trout stomachs at various intervals indicate that at least 50 percent of the total food fed to each fish was digested in 14 hours at temperatures between 32°F. and 35°F.

TROUT MORTALITY

Winter has long been suspected as the season of greatest trout mortality. Needham, Moffett, and Slater (1945) found that overwinter decrease in brown trout in Convict Creek averaged 60 percent over 4 years in uncontrolled stream sections. This loss was attributed to the severity of winter conditions, principally drifting snow and ice. Needham and Slater (1944) report the smothering of several hundred trout by the collapse of a snowbank into a rearing pond.

Because there was light snowfall in the winter of 1951 in the Convict Creek area, there was no opportunity to study the effects of this factor. A type of winter mortality occurred during early January in which trout of all sizes were victims of cold weather. On January 10, following 3 days of low temperatures, 63 trout were found stranded on damp rocks at the bottom of shallow pools in a flood control bypass. Heavy nightly subsurface ice formations at the flood control structure, combined with incomplete daily thawings, had progressively diminished the flow of water into the bypass. In the early morning hours of January 10, water had ceased to flow into the bypass and the fish were suffocated where the water drained into the porous substrate. Layers of surface ice insulated the fish from freezing. This type of mortality was not confined to the bypass. Several days later, after warm winds and sunshine had melted surface ice from the stream, other dead trout were observed in similar situations, some in natural side channels as far as 1½ miles above the Experiment Station. No other cause of mortality could be directly attributed to winter conditions in the present study. Predation was unimportant at Convict Creek, since no predatory birds or mammals were seen during the study nor were their tracks or signs found. A 24-inch female brown trout was found to have eaten another trout about 6 inches long.

Throughout the winter, very few trout seen or captured were in poor condition. However, dead and emaciated trout recovered within the experimental sections between November 7, 1950, and April 21, 1951, totaled 7 brown and 46 rainbow trout. Thin, weakened fish, carried downstream by the current, were retrieved dead or dying at the screen structures. The higher percentage of hatchery rainbow trout found is indicative of their greater susceptibility to winter emaciation than wild brown trout. This mortality is peculiar in that it never occurred in periods of freezing weather. Between January 1 and March 15, only 11 dead trout were picked up at the screens, and these appeared only in the warmest weather. Possibly this is the result of a lower metabolic rate in colder water.

If any line is to be drawn between advantageous and detrimental winter conditions, it must be one of degree. The winter experienced during this study is considered mild because of the lack of snow. Low air and water temperatures occurred (Table 2) but were probably shorter in duration than in winters having more severe climatic conditions. Generally, trout fared quite well, for ice conditions that caused a small initial winter mortality, later offered fish cover and food. It is probable that lower temperatures, more continuous cold weather, heavy snowfalls, or a combination of these would have a more drastic effect on fish and other stream life.

OPERATIONAL HAZARDS OF EXPERIMENTAL SECTIONS

The year 1951 marked the first winter operation of the Convict Creek Station. The main purpose was to determine over-winter survival rates of wild and hatchery trout planted in experimental stream sections. It was found impossible to pass stream-borne ice and slush through the screens and, when the water temperature dropped to 32° F., ice formed in the screen meshes creating dams which forced the water to flow over or around water control structures and channels. Although it was observed that trout were reluctant to migrate any distance when water temperatures were below 42° F., it was nevertheless apparent that there existed abundant opportunity for escape of fish from the experimental sections during periods of overflow. Strong winds greatly increased the flow of Convict Creek by increasing out-flow from the lake 2 miles above the station, and also caused formations of heavy clumps of spray ice to form around the screen structures. Surface ice often froze screens solidly in the concrete slots of the flumes, making it impossible to remove them for cleaning. High winds frequently blew heavy quantities of leaves into the stream which plugged screens before they could be removed, and caused overflow around or over them.

In spite of these difficulties when the fish were recovered from the stream sections during the last week of April, 1951, approximately 50 percent of the marked trout stocked in November, 1950, had survived.

ACKNOWLEDGMENTS

We wish to thank Reed S. Nielson, Chief of the California-Nevada Inland Fishery Investigations of the Fish and Wildlife Service, who provided many of the facilities and much good advice in the course of the field work, and Bobby D. Combs, Fishery Research Biologist, who gave much aid in the course of his duties as Supervisor of the Convict Creek Station. To Dr. R. L. Usinger of the Division of Entomology, University of California, we are indebted for aid in determining many of the aquatic insects and for his initial reading of the manuscript. The aquatic oligochaetes were determined by Dr. Henry W. Olson of Wilson Teachers College, Washington, D. C. Records of stream flows on Convict Creek were obtained from the City of Los Angeles, Department of Water and Power.

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REVIEW OF THE FISH FARMING INDUSTRY IN ISRAEL

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ABSTRACT

Israel has established fish farming with carp as the principal species. It is a successful agricultural practice because production is good and land otherwise useless is employed. Fish ponds are fertilized and fish are also fed directly with oil cake, lupin seeds, and grain husks. Production is as high as 1,750 kilograms per hectare. Research in progress and general operation of ponds is described.

This review deals with the fish-farming industry of Israel which in recent years has become an important factor in the supply of animal protein to the population. In spite of the rapid development of all branches of agriculture in Israel, the provision of an adequate food supply is one of the most difficult problems which faces the country where the rapid rate of immigration has doubled the population in the last 3 years.

Fish farming in Israel is a relatively recent innovation. The first fish ponds were dug in 1938 by settlers who learned the fundamentals of fish farming in Yugoslavia. They brought with them a number of common carp. During the first year, the local conditions and especially the many months of high average temperature proved to be well suited to the cultivation of these fish. Yields were found to be much greater than those usually obtained in Central Europe.

The number of fish ponds was rapidly increased. In 1938 the total pond area was 10 hectares. By 1940 it had expanded to 200 hectares and now approaches 3,000 hectares giving a yield of 5,000 tons of fish per annum. The present output comprises 25 percent of the local consumption of fish.

Factors which have contributed to the rapid expansion of fish farming in Israel were, first, the existence of large abandoned and undeveloped areas, including swamps and salty lands, which though unfit for agriculture could be used successfully for fish ponds; and second, the existence of many sources of brackish water (1,000 or more parts per million of

chlorine) which are unfit for use in irrigation but nevertheless satisfactory for fish breeding. The utilization of these sources is of great importance in view of the shortage of water throughout the country.

Species of fish bred.—The only fish which is bred on a commercial scale is the carp (*Cyprinus carpio*) of Yugoslav origin but recently attempts have been made to breed carp brought from Switzerland and France. The carp was chosen for cultivation because of its suitability to intensive breeding methods and the ease with which it can be fattened by artificial feeding. Furthermore it was found to adapt itself well to the local climatic conditions and to be relatively insensitive to high temperatures and lack of oxygen. An additional advantage of the carp, which is an essential in all planned fish-breeding schemes, is its ability to spawn profusely in an artificial environment.

Experiments are at present being conducted in an attempt to find other types of fish suitable for breeding in Israel. The successful solution of this problem will permit a more complete exploitation by the fish of the foodstuffs available in the ponds, and will offer a wider choice of diet to the population. Four species are being investigated. The rainbow trout (*Salmo gairdneri irideus*) is being cultivated in a small area in the north of Israel where water is plentiful and of low and constant temperature. Preliminary experiments on the tench (*Tinca tinca*) seem to indicate that it is not suited to local conditions. The grey mullet (*Mugil cephalus*) is a marine species which thrives well in brackish ponds. The fry is caught in brackish rivers near the sea and transferred for cultivation to special ponds. The main problems are the catching of the fry in sufficient numbers, and their separation from other fry. Several species of *Tilapia* are common in local waters. It is often introduced in fish ponds with the water supply. Certain types of *Tilapia* appear to be suited for breeding in special ponds. The introduction of new species from the Far East, especially the Philippines and India, is contemplated.

Construction of ponds.—The size, shape, and depth of the ponds is largely dictated by the topographical features of the country. The area of individual ponds varies between 1 and 8 hectares. About 4 percent of the area is allocated to small ponds not larger than 0.2 hectares which are used for spawning. The depth of the ponds varies between 0.5 and 2 meters, being usually 1 meter. Ponds are constructed with the help of excavating and leveling machines. In flat areas where any shape can be made at will a rectangular form is preferred. Special openings are constructed at the lowest points in the ponds to facilitate the removal of the water and its re-use where shortage of water makes this necessary.

Methods of breeding.—In the breeding of fish, as in other branches of Israel's agriculture, there is a tendency to intensify the projects as far as possible by scientific planning. This procedure is necessary because there is a lack of fertile areas and a rapidly increasing population. The breeding program is based on a yearly or biennial period of growth. The desired size of fish for marketing is 400 to 500 grams.

The ponds are emptied twice a year, to permit an accurate control of the number and size of the fish, and the elimination of unwanted fish which may have been introduced through the water supply. The detailed planning of the breeding and stocking program is essential for the maximum utilization of the available water area throughout the growing season.

The fish used for spawning are carefully selected and transferred to special ponds the bottoms of which are covered with pine branches for the deposition of the spawn. Two or three male fish are introduced into each spawning pond together with one or two females. Spawning usually takes place about the middle of April and results in the production of 300,000 to 500,000 fry. Towards the end of May, the fry are transferred to the nursery ponds which comprise about 10 percent of the total pond area. The fry are kept in the nursery ponds till they reach an average weight of 50-100 grams when there are about 30,000 fish per hectare. Some of the fish are removed from the spawning ponds and kept at a density of 100,000 to 1,000,000 per hectare as a reserve store for additional stocking.

The fry are transferred from the nursery ponds to the fattening ponds in accordance with the production schedule, and kept there till June of the following year. The density in the fattening ponds is 3,000 to 4,500 fish per hectare, depending on the fertility of the pond and the desired market-size of the fish. In poor ponds it has been found that increase in the density of stocking and removal of the fish, when they reach a size of about 300 grams, results in yields approaching those obtained in fertile ponds.

In many fattening ponds containing fish weighing not less than 300 grams, it is usual to introduce equal numbers of small fry up to 10 grams in weight. This technique is based on the assumption that the food of the small fish is different from that of the large fish and that better exploitation of the pond is thus obtained. Furthermore, under these conditions, a single pond is made to serve as both nursery and fattening pond at the same time. The emptying of the ponds throughout the country is so ordered as to ensure an even supply of fish over most of the year.

Feeding and fertilizing.—Intensive artificial feeding, manuring, and fertilization of the water are essential for the production of high yields. The fish are artificially fed from the earliest stages. The main foods used are oil cakes, lupin seeds, and the husks of various grains. The greater part of the food used consists of oilcake, the residue from the extraction of oil from cotton seed. It contains about 36 percent protein and 3 to 4 kilograms of this food are required to produce 1 kilogram of marketable fish.

At present most of the oilcake is imported but with the extension of local oil manufacture to meet the requirements of the population it is hoped that sufficient oilcake to cover the requirements of the fish-breed-

ing industry will be produced. The possibility of growing foodstuffs such as lupins is also being investigated. The determination of the efficiency of feeding and the required feeding levels is achieved by weighing a sample of about 200 fish in each pond at fortnightly intervals.

Fertilization of the ponds is carried out by using up to 10 cubic meters of stable manure per hectare per annum, together with the occasional use of poultry manure and the liberal use of chemical fertilizers which are administered in the form of superphosphate (1,500 kilograms per hectare) and ammonium sulphate (500 kilograms per hectare). It is usually not necessary to add potassium. The times of fertilization and quantities required are determined by chemical analysis of the pond water, in so far as existing facilities enable this to be done.

In recent years there has been an increasing tendency to drain most of the pond area during winter when little growth of the fish takes place. It is usual to sow the areas with various crops since this practice increases the subsequent yields of the fish, and puts the land to good use during this otherwise unproductive period. It also reduces the danger of fish diseases.

Productivity of ponds.—The yields obtained vary from area to area, according to climatic conditions, the nature of the soil, and the amount and quality of the water. The average yield during the last year was 1,750 kilograms per hectare. It is noteworthy that during the few years of fish breeding in Israel, yields have been steadily increasing year by year. Further improvements in technique and the elimination of losses from diseases and parasites will no doubt increase the yield still further.

Special techniques.—The warm climate and the desirability of supplying living fish to the markets have resulted in the development of appropriate transport methods. Large trucks are equipped with tanks capable of holding $4\frac{1}{2}$ cubic meters of water and 3,000 kilograms of fish. During transportation over distances up to 250 kilometers, and up to 8 hours duration, an adequate supply of oxygen is ensured by bubbling oxygen from a cylinder through the tanks.

An important development which facilitates the removal of fish from the ponds consists of a concrete box $\frac{1}{2}$ by 2 by 8 meters with an opening at both ends, which is built in the deepest part of the pond. When the pond is to be emptied, the water is removed till the area of the pond is much reduced. Fresh water is then introduced through the concrete box. All the fish swim towards the fresh water source where they concentrate within the concrete box. From there they can be transferred by a small elevator directly into the tanks for transportation. This development does away with the necessity of netting the fish.

Diseases of pond fish.—Soon after the introduction of fish farming in Israel, various diseases appeared and spread rapidly because fish were crowded and ponds were interconnected. The majority of the diseases

and the occurrence of parasites are sporadic in nature, and in the form of local epidemics. Although local losses are sometimes serious, the total losses from the country-wide point of view are relatively small.

Some of the diseases occurring locally among the carp are known wherever these fish are grown, while others appear with specific local characteristics. Entirely new diseases and parasites have also been observed. Extensive mortality accompanied by heavy economic losses has resulted from the development of the free-living toxin-producing phytoflagellate, *Prymnesium parvum*. This development has for some years threatened the existence of fish farming in brackish water areas where the water contains more than 350 p.p.m. of chlorine. It thus constitutes a serious obstacle in one-quarter of the fish breeding areas of Israel. In spite of a partially practical solution to the problem which was found in the specific lethal effect of a low concentration of ammonia on the *Prymnesia* the danger is still a serious one. Much attention is now being devoted to the investigation of the biology of *Prymnesium*, methods for its suppression, and the nature of its toxic principles.

In some ponds during the early hours of the morning in the summer months, considerable mortality results from lack of oxygen in the water. This deficiency occurs most commonly in ponds with a water bloom composed of various Cyanophaceae. Highly toxic species have recently been found among these algae.

Research.—Although fish breeding was introduced to Israel as an industry having a long history in various other countries, the problems which arise from the need to adapt the technique to local conditions require constant research. This research is carried out by the Department of Fisheries of the Ministry of Agriculture at a Central Experimental Station and several field stations. The field stations are concerned with the recognition and solution of the problems arising within their respective regions, and cooperate on a wider basis with the Central Research Station. Among the main problems dealt with by the central station of the Ministry of Agriculture are those of feeding fish and fertilization of ponds. The suitability of new types of fish for breeding, and methods for the prevention of fish diseases are being investigated. The problem of the genetic selection of appropriate strains of fish is also under consideration.

The important place occupied by fish farming in the agricultural economy of Israel is evident from the following facts:

(1) Fish farming has increased the agricultural potential of Israel by the utilization of lands and water unfit for other purposes. In certain areas previously deserted, it is the only basis for settlement of the land.

(2) The relatively short time required for the profitable establishment of this branch of agriculture has given new settlements the time and financial means required to overcome difficulties inherent in other branches.

(3) Part of the fish pond areas is used in turn for fish farming and the growing of crops. Thus, the intensive fertilization of the pond is beneficial for the crops, and the crops, in turn, improve the land for subsequent fish farming.

(4) Fish farming utilizes to good effect the waste product of the manufacture of oil from cotton seed.

(5) Reservoirs which are to be erected in accordance with general irrigation schemes may be used also for fish breeding, thus contributing to the economic benefits of such schemes. A beginning has already been made in this direction in the Negev.

RATE OF EXPLOITATION OF WILD EASTERN BROOK TROUT AND BROWN TROUT POPULATIONS IN THE PIGEON RIVER, OTSEGO COUNTY, MICHIGAN¹

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ABSTRACT

The Pigeon River Trout Research Area contains 4.8 miles of trout stream averaging 40 feet in width. In this area a complete census of fishing is accomplished by means of a compulsory permit system. Estimates of the wild trout population were made in September of 1949 and of 1950 immediately following the close of the trout season. Comparison of the total catch with the population remaining at the close of the season indicates that wild eastern brook trout are much easier to exploit than wild brown trout. Combining data for 1949 and 1950, anglers took 3.0 brook trout for each one remaining at the close of the season. For brown trout, only 0.4 fish was caught for each one remaining.

INTRODUCTION

The Pigeon River is located at the northeastern tip of the Lower Peninsula of Michigan. It flows in a northerly direction from its source a few miles east of the town of Gaylord, emptying into Lake Huron by way of Mullett Lake and the Cheboygan River. The drainage area is roughly 35 miles long and 10 miles wide and is largely covered with second growth pine and hardwood forest. A portion of the Pigeon River was selected as the site for a trout research area because there was a large amount of state-owned stream frontage and also because it was believed to be representative of many other Michigan trout streams.

The Pigeon River Trout Research Area comprises 4.8 miles of trout stream and a series of seven small lakes suitable for trout. The portion of the stream under study has been arbitrarily divided into four fishing sections of nearly equal length, hereafter referred to as Sections A (furthest downstream), B, C, and D. Preliminary investigations with an electric shocker disclosed that the numbers of trout present in Section A differed markedly from the numbers in other sections, although the physical features of the sections are similar (Table 1). The upper three sections (B, C, and D) support a moderate wild population of both eastern brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). Rainbow trout (*Salmo gairdneri*) are present in much smaller numbers. Much of the lower section (A) is sluggish with a sandy bottom and contains fewer trout.

¹Contribution from the Michigan Institute for Fisheries Research.

A permit-type of creel census was operated on the experimental waters during the seasons of 1949 and 1950. In Michigan, the general trout season opens on the last Saturday in April and ends on the second Sunday in September, resulting in a 135-day season. Each fisherman desiring to fish a particular portion of the stream was required to register at a centrally-located checking station and obtain a permit.

TABLE 1.—*Morphometry of Pigeon River Trout Research Area survey of 1949-1950.*

Item	Section A	Section B	Section C	Section D	Total
Length—miles.....	1.31	1.19	1.13	1.18	4.80
Average width—feet.....	45	41	40	40	41
Area—acres.....	7.16	5.90	5.39	5.65	24.10
Percent gradient.....	0.18	0.18	0.23	0.15	0.18

When he stopped fishing in that particular section of the stream, he was required to return his permit to the checking station and report his success. No charge was made for a permit and a person could fish in as many sections of the stream as he wished. Permits were issued at any time of the day or night. A general willingness on the part of the public to cooperate with this program provided an accurate record of the results of fishing in the area. The present discussion deals with the yield of wild trout to the angler in relation to the trout population of the stream as measured by estimates of the residual population at the end of the season.

METHOD OF ESTIMATING TROUT POPULATIONS IN PIGEON RIVER

The general procedure of the study is as follows. The 4.8 miles of experimental stream is traversed by a crew of five men using an A. C. electric shocker. Each trout captured is measured to the nearest inch, fin-clipped, and immediately returned to the stream. At the conclusion of the first run through the stream, there are a known number of marked trout present which are classified as to species and size frequency. Presumably these fish are distributed throughout the stream in about the same manner as they were prior to the initial sampling.

The same section of stream is shocked again 3 to 4 days later. All fish again are measured and data on the number of marked and unmarked fish taken are recorded. On the assumption that marked and unmarked trout are captured in the second run in direct proportion to their numbers present in the stream, the total number of all species of trout in the 4.8 miles of stream is estimated. Since large fish are captured more easily than small ones, it is necessary to make separate estimates for different sizes.

The total estimate may be further subdivided into numbers of fish of each species on the assumption that each species is represented in the total population in direct proportion to its representation in all of the sampling.

A similar breakdown may be made of the numbers of fish in the different portions of the stream, assuming that the efficiency of capture of the trout does not change markedly from one section of the stream to another. This method of subdividing the total estimate is believed to be more accurate than estimating the numbers of fish of each size and species, in small portions of the stream separately and combining all the individual estimates for the total population. The total number of all fish taken in the two different sampling runs of the entire area and the numbers taken in component portions indicate the constancy of the shocker in catching fish (Table 2). Also, as will be shown later, the population estimates obtained were consistent with the creel census data secured during the same seasons.

These estimates are of the trout populations only although small numbers of northern muddler (*Cottus b. bairdi*), western blacknose dace (*Rhinichthys atratulus meleagris*), northern creek chub (*Semotilus a. atromaculatus*), and the common white sucker (*Catostomus c. commersonni*) are also present.

The mark-and-recapture method used in estimating the trout population is dependent upon the efficiency of the electric shocker. Although the use of electricity for catching fish is by no means new (Burr, 1932; Haskell, 1940) its application to the estimation of stream populations has not been fully exploited. The present study represents an advance over attempts to estimate stream populations with seines or water diversion (Hoover, 1938; Needham, Moffett and Slater, 1945; Shetter and Hazzard, 1939; Shetter and Leonard, 1943). It is also believed to be somewhat better than attempts to estimate total populations of larger portions of streams from randomly selected small samples taken with electric shockers (Smith, Johnson and Hiner, 1949; Schuck, 1945; Mottley, 1942), in that the data obtained are based on a large sample of the population of a continuous 4.8-mile portion of a stream. Unpublished information (D. S. Shetter), as well as our present observations, indicate that the variation in population density may be so great in small adjacent portions of trout streams that the total estimate of a large portion is more efficient and more accurate than the results from an appreciable number of randomly-selected small areas. The method employed in this study is similar to that used by Shetter, 1950.

The accuracy of the method depends to a large extent on the adequacy of the sample and upon the validity of several assumptions discussed below. It should be emphasized that the data obtained in this and similar studies are only approximations of the actual populations. It is necessary to assume that the initial capture of the fish by an A. C. electric shocker, marking by fin-clipping a portion of the caudal fin,

and immediately returning them to the same portion of the stream, do not measurably affect the recapture of the fish 3 to 4 days later. Any large mortality, movement from the sampling area, or future avoidance of capture would adversely affect the accuracy of the estimate. Exact quantitative information on these possible sources of error are lacking. However, observations made at the research area during 2 years of extensive use of the shocker support the first assumption. If the shocking method of collecting fish results in an increased mortality, the amount of shocking done in the past 2 years should have decreased the population markedly. Such a decrease was not demonstrated by creel census records or by population estimates.

TABLE 3.—Number marked (*M*) and percentage of recovery (*R*) of wild trout in Pigeon River, 1949—expressed by species, size, and stream section.

Item	Size group—inches					
	2.0—3.9		4.0—6.9		7.0 and over (legal size)	
	M	R	M	R	M	R
September, 1949						
Brook trout						
Section A.....	9	11.1	38	13.2	4	50.0
Section B.....	33	0.0	64	14.1	12	41.7
Section C.....	114	9.6	212	28.8	26	34.6
Section D.....	73	9.6	235	20.4	49	22.4
All sections.....	229	8.3	549	22.4	91	29.7
Brown trout						
Section A.....	12	8.3	30	23.3	34	29.4
Section B.....	38	2.6	35	34.3	62	29.0
Section C.....	33	12.1	38	36.8	56	32.1
Section D.....	10	30.0	16	31.3	53	30.2
All sections.....	93	9.7	119	31.9	205	30.2
Brook and brown trout combined						
Section A.....	21	9.5	68	17.6	38	31.6
Section B.....	71	1.4	99	21.2	74	31.1
Section C.....	147	10.2	250	30.0	82	32.9
Section D.....	83	12.0	251	21.1	102	26.5
All sections.....	322	8.7	668	24.1	296	30.1

During the spring of 1951 observations on the movement of wild trout following shocking and fin-clipping were made. Several hundred wild trout were collected with the shocker, fin-clipped, and returned to the stream. Subsequent recoveries by anglers from these experiments indicate very little movement of marked fish out of the section in which they were originally captured and marked. Also, this same program of shocking and marking indicated that fish were not avoiding recapture to any great extent. During the later runs with the shocker through the sections sampled, a large proportion of the fish captured were those that had previously been captured and marked. These observations, while not exact, lend support to the assumption that errors from mortality, movement, or changes in catchability are minimal.

It is further assumed that the three species of trout encountered in the Pigeon River (eastern brook, brown, and rainbow) are equally susceptible to capture by this method. In examining the figures for eastern brook and brown trout of various sizes for the 2 years, no consistent differences in rate of recovery between these two species are apparent (Tables 3 and 4). The small number of rainbow trout encountered does not warrant their inclusion in the table. Differences in the rate of recovery appear to be random and relatively small when

TABLE 4.—Number marked (*M*) and percentage of recovery (*R*) of wild trout in Pigeon River—expressed by species, size, and stream section.

Item	Size group—_inches							
	2.0—4.9		5.0—6.9		7.0—9.9		10.0 and over	
	M	R	M	R	M	R	M	R
September, 1950								
Brook trout								
Section A.....	27	3.7	24	16.7	12	33.3	1	0.0
Section B.....	60	5.0	43	16.3	20	25.0	0	.....
Section C.....	76	2.6	83	9.6	28	14.3	0	.....
Section D.....	120	10.0	129	14.7	43	32.6	0	.....
All sections	283	6.4	279	13.6	103	26.2	1	0.0
Brown trout								
Section A.....	4	25.0	2	0.0	19	21.1	11	36.4
Section B.....	38	5.3	25	32.0	49	34.7	22	45.4
Section C.....	14	0.0	18	5.6	49	24.5	17	23.5
Section D.....	12	0.0	10	40.0	48	39.6	18	50.0
All sections	68	4.4	55	23.6	165	31.5	68	39.7
Brook and brown trout combined								
Section A.....	31	6.5	26	15.4	31	25.8	12	33.3
Section B.....	98	5.1	68	22.1	69	31.9	22	45.4
Section C.....	90	2.2	101	8.9	77	20.8	17	23.5
Section D.....	132	9.1	139	16.5	91	36.3	18	50.0
All sections	351	6.0	334	15.3	268	29.5	69	39.1

the different sections of the stream are compared. There is a consistent difference, however, in the recovery rate of trout of different sizes, and these differences must be considered in the method of estimating the total population. The small fish are not only harder to stun with the shocker but are also harder for the operator to see, and therefore are less easily captured than larger fish.

ESTIMATES OF POPULATIONS

A population estimate of the trout present in the research area of the Pigeon River was made in September, 1949, immediately after the close of the trout season. This estimate disclosed a residual population of legal-sized wild fish per acre of 10.9 brook trout, 23.8 brown trout, and 0.6 rainbow trout (Table 5). In September, 1950, a population esti-

mate was again made for the same portion of the river. At the close of this season there was a residual population of legal-sized fish per acre of 12.4 brook trout, 27.7 brown trout, and 0.5 rainbow trout.

CATCH STATISTICS FOR 1949 AND 1950

The creel census data for 1949 and 1950 represent the complete yield of the stream to the anglers. Fishing intensity was high with more than 2,000 fishing trips (or 250 to 280 hours per acre) recorded in

TABLE 5.—*Estimates of the wild trout population of 4.8 miles of Pigeon River, Otsego County, Michigan, 1949-1950—expressed by section, species, and size group.*

Species, year, and stream section	Size group—total length in inches					
	2.0—4.9		5.0—6.9		7.0 (Legal size) larger	
	Number of trout per acre	Pounds per acre	Number of trout per acre	Pounds per acre	Number of trout per acre	Pounds per acre
Brook trout						
September, 1949						
Section A.....	26.4	0.53	9.1	0.74	3.5	0.58
Section B.....	92.7	1.85	16.3	1.33	5.3	0.88
Section C.....	378.7	7.56	67.9	5.56	13.5	2.26
Section D.....	277.7	5.55	68.0	5.57	23.5	3.94
All sections.....	180.3	3.60	37.8	3.10	10.9	1.82
September, 1950						
Section A.....	64.9	1.43	19.3	1.58	7.5	1.26
Section B.....	168.6	3.71	38.5	3.15	10.5	1.75
Section C.....	255.3	5.62	77.9	6.38	11.1	1.86
Section D.....	465.8	10.26	148.3	12.14	21.8	3.63
All sections.....	226.9	5.00	67.3	5.51	12.4	2.07
Brown trout						
September, 1949						
Section A.....	24.2	0.45	4.8	0.46	12.6	3.79
Section B.....	76.9	1.42	9.7	0.91	29.8	8.99
Section C.....	104.8	1.93	11.1	1.04	30.2	9.12
Section D.....	41.6	0.77	4.1	0.38	25.7	7.74
All sections.....	59.2	1.09	7.3	0.68	23.8	7.18
September, 1950						
Section A.....	23.3	0.48	1.3	0.12	11.9	3.59
Section B.....	116.3	2.39	24.9	2.34	33.9	10.25
Section C.....	58.4	1.20	14.8	1.39	31.0	9.37
Section D.....	68.8	1.41	13.1	1.23	38.1	11.51
All sections.....	64.6	1.33	12.9	1.21	27.7	8.37
Rainbow trout						
September, 1949						
Section A.....	0	0	0	0	1.1	0.18
Section B.....	1.2	0.02	0	0	0.8	0.14
Section C.....	3.5	0.05	0	0	0	0
Section D.....	0	0	0	0	0.4	0.06
All sections.....	1.1	0.02	0	0	0.6	0.10
September, 1950						
Section A.....	1.3	0.02	0	0	0.4	0.07
Section B.....	0	0	2.5	0.23	0.3	0.06
Section C.....	5.2	0.07	1.7	0.15	0.9	0.15
Section D.....	43.9	0.61	0.5	0.05	0.5	0.09
All sections.....	11.8	0.16	1.1	0.10	0.5	0.09

each of the two seasons. These fishermen caught approximately 1,000 wild trout in each of the 2 years, with brook trout outnumbering brown trout by 3 to 1. Wild rainbow trout were rarely recorded in the catch (Table 6).

Comparing the data from the creel census with that of the population estimates, we find that there is considerable agreement as to the distribution of the trout in the different portions of the stream. For example, Sections C and D yielded the greatest return of wild brook trout to the anglers. The population estimates of brook trout in these sections

TABLE 6.—*The total yield of legal-sized trout to fishermen and the residual population in September in the Pigeon River—expressed as number and pounds of trout per acre.*

Species, year, and stream section	Yield to anglers		Residual population	
	Number per acre	Pounds per acre	Number per acre	Pounds per acre
Brook trout				
1949				
Section A.....	13.1	2.24	3.5	0.58
Section B.....	25.3	4.30	5.3	0.88
Section C.....	52.7	8.97	13.5	2.26
Section D.....	47.1	8.02	23.5	3.94
All sections.....	32.9	5.60	10.9	1.82
Brook trout				
1950				
Section A.....	13.0	2.01	7.5	1.26
Section B.....	25.8	4.31	10.5	1.75
Section C.....	57.7	8.61	11.1	1.86
Section D.....	64.2	9.55	21.8	3.63
All sections.....	38.1	5.82	12.4	2.07
Brown trout				
1949				
Section A.....	3.8	1.00	12.6	3.79
Section B.....	11.2	2.98	29.8	8.99
Section C.....	11.7	3.11	30.2	9.12
Section D.....	7.4	1.98	25.7	7.74
All sections.....	8.2	2.19	23.8	7.18
Brown trout				
1950				
Section A.....	3.8	0.93	11.9	3.59
Section B.....	15.4	3.66	33.9	10.25
Section C.....	16.3	3.98	31.0	9.37
Section D.....	8.7	2.35	38.1	11.51
All sections.....	10.6	2.61	27.7	8.37
Rainbow trout				
1949				
Section A.....	2.1	0.55	1.1	0.18
Section B.....	2.9	0.75	0.8	0.14
Section C.....	3.0	0.77	0.0	0.00
Section D.....	1.6	0.42	0.4	0.06
All sections.....	2.4	0.62	0.6	0.10
Rainbow trout				
1950				
Section A.....	0.4	0.04	0.4	0.07
Section B.....	1.4	0.21	0.3	0.06
Section C.....	0.6	0.07	0.9	0.15
Section D.....	0.4	0.04	0.5	0.09
All sections.....	0.7	0.14	0.5	0.09

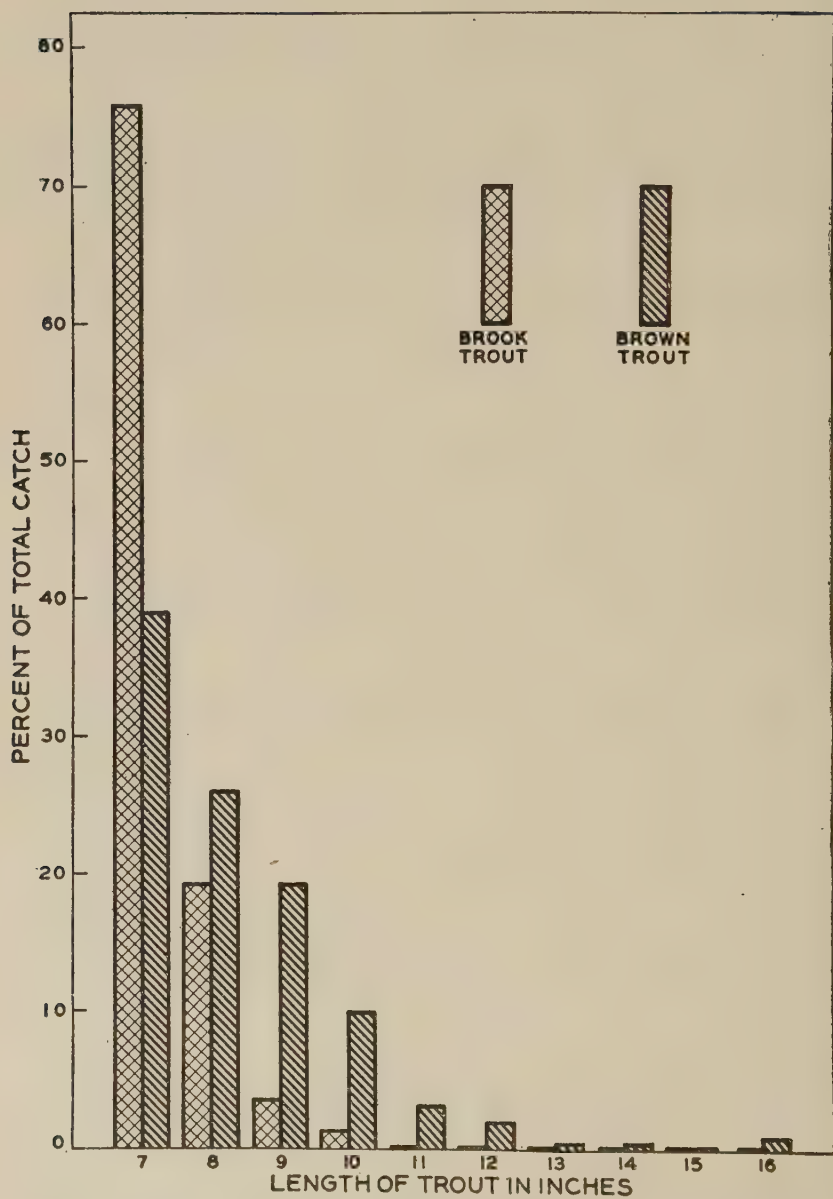


FIGURE 1.—Length frequency of brown and brook trout in the anglers' catch expressed as percent of total catch.

also were high when compared with the other sections. Sections B and C had a high population density of brown trout, heavy fishing pressure, and also gave the highest return to fishermen for this species (Table 6).

It will be observed that there are large differences in population density (as measured both by the catch and by population estimates) between these relatively small adjacent portions of the stream. The physical characteristics of the river differ only slightly from one section to another (Table 1). The difference in maximum water temperatures is also slight. A maximum temperature of 80° F. has been recorded at the upper end of Section B and 75° F. at the upper end of Section D, which is the upstream boundary of the experimental area.

EXPLOITATION OF WILD TROUT

It is important in the management of a sport fishery to know the effect of fishing on the available stocks. This rate of exploitation may be estimated in several ways. The total catch per acre has been compared with the population remaining at the close of the season (Table 6). For the brook trout, three fish were caught for each one remaining in the stream. This ratio was reversed for brown trout with only one fish being caught for each three remaining at the close of the season.

This difference in exploitation by anglers of brook and brown trout is shown also by the size-frequency of the catch (Figure 1). The two species are growing at similar rates in this stream, yet very few brook trout live long enough to reach 10 inches. Brown trout over 10 inches long are caught each year, and many more of this size are left after the season closes. The relative availability of brook and brown trout to the angler was noted by Shetter (1950) and Schuck (1942). However, neither author mentioned what appears to be the most logical explanation of this phenomenon; that there is an inherent ability on the part of the brown trout to avoid capture that is not shared in equal measure with the brook trout. It has been known by many anglers for some time that brown trout are not so easily fooled as brook trout, but few data have previously been advanced to support this belief.

The question of how the eastern brook trout maintains itself in competition with brown trout, in view of the much heavier yield and much smaller residual population of the former has been raised. It is known that eastern brook trout mature and spawn at an earlier age and smaller size than brown trout. In the experimental portion of the Pigeon River many 5- to 6.9-inch eastern brook trout spawn while brown trout less than 9 inches long are seldom mature. This fact may account for the success of the brook trout in maintaining themselves in the Pigeon River (Table 4).

ACKNOWLEDGMENT

General supervision of this study was furnished by Dr. A. S. Hazzard. Assistance in obtaining creel census data and population estimates as well as laboratory assistance in tabulation of data was given by Messrs. W. H. Tody, J. H. Claridge, G. F. Myers, H. Gowing, R. J. Ellis, N. G. Benson, D. G. Tesman, W. C. Wagner, K. G. Fukano, and E. H. Andersen.

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LIFE HISTORY OF THE CUTTHROAT TROUT, *SALMO CLARKI* RICHARDSON, IN LOGAN RIVER, UTAH¹

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ABSTRACT

This study of the cutthroat trout in Logan River, Utah, was based on 306 specimens collected during 1948 and 1949 with an alternating-current electric shocking machine. Cutthroat trout composed 24 percent of the anglers' catch during 1948 and 31.5 percent in 1949. The greatest numbers were found in areas with a high stream gradient. An estimated minimum number of 43.6 pounds of cutthroat per acre and 565 fish per mile was obtained from a series of shocking operations during 1949. Scale analysis was employed in determining the age of the fish. With a scale magnification of 50x, the body-scale (L/S) relationship of the cutthroat trout can be described as a curvilinear regression line, and expressed by the equation:

$$L = 3.411 S^{1.2006}$$

The smallest average annual growth increment was 53 millimeters. This was based on a growing season of approximately 200 days. Growth began in the latter part of March and extended to early October.

The relationship between standard length and weight was expressed mathematically as:

$$W = 4.344 \times 10^{-5} L^{2.8253}$$

where W equals weight in grams and L equals the standard length in millimeters. The coefficient of condition decreased as the length of the fish increased. Male cutthroat trout had slightly more weight per unit of length than females. Of 142 fish marked with jaw tags, 15 were recovered; none moved out of the one-tenth-mile area where they were originally released. The spawning period of the cutthroat trout in this area lasted from early April to the middle of August, but most fish spawned before the middle of July. Adult females ranged in size from 11 inches downward. Slightly more females than males were present in a total of 35 separate collections.

Insects were the main item in the diet of the Logan River cutthroat trout. Ephemeroptera, Trichoptera, and Diptera were the principal aquatic orders taken, while the most important terrestrial order was Coleoptera. Small numbers of fish eggs eaten indicated that survival was not affected. Only two occurrences of fish were found in the entire food habits study. The small size of the cutthroat trout in this area is in part attributable to the almost total absence of forage fish in the upper Logan River.

INTRODUCTION

The study of the cutthroat trout (*Salmo clarki*) in the Logan River drainage was initiated by the Wildlife Management Department of Utah State Agricultural College in cooperation with the Utah Cooper-

¹Contribution from Utah State Agricultural College, Wildlife Management Department, Project 131.

ative Wildlife Research Unit² during May, 1948. The taking of fish was terminated in November 1949, although several trips were made into the study area as late as January, 1950. This inquiry was designed to provide life-history information of the cutthroat trout as one part of a comprehensive fishery investigation of this drainage. Other phases of this investigation completed to date include studies of the fish population and yield to anglers by Thoreson (1949), and Pechacek (1950); and a life history study of the mountain whitefish (*Prosopium williamsi*) by Sigler (1951).

The following fishes are present in Logan River: cutthroat trout, brown trout (*Salmo trutta fario*), coast rainbow trout (*Salmo gairdneri irideus*), eastern brook trout (*Salvelinus fontinalis*), mountain whitefish, upper snake muddler (*Cottus sp.*), and smallfin redbelt shiner (*Richardsonius balteatus hydrophlox*). The Utah cutthroat trout (*Salmo clarki utah*), the mountain whitefish, and the upper snake muddler were presumably native to this drainage. The cutthroat trout under consideration will be designated as *Salmo clarki* since the subspecific identification is impossible. The Utah cutthroat trout, originally found in this drainage, is believed at the present time to be extinct.³ In all probability, its eradication was due, in part, to the indiscriminate planting of the Yellowstone cutthroat (*Salmo clarki lewisi*). This introduction may have resulted in hybridization of the subspecies of *Salmo clarki*. In addition, introduced rainbow trout further complicated identification by hybridizing with the cutthroat trout.

DESCRIPTION OF THE AREA

The study area embraced the Logan River watershed from the Idaho state line (elevation 7,500 feet) to a point one-half mile below the dam located just east of Logan City (elevation 4,700 feet), a distance of 32.6 highway miles (Figure 1). Air and water temperatures for the shocking stations were taken from April to October. Water temperatures ranged from 37° to 50° F., but rarely exceeded 48° F. Winter conditions are very severe. Brown (1935) states that the stream has an average gradient of 70 feet per mile. The cutthroat-trout study area in the headwaters has a somewhat higher gradient than the portion of the river below the mouth of Temple Fork. Upper Logan River, west of Beaver Mountain, has a gradient of 167 feet per mile, and Beaver Creek and Temple Fork have gradients of 200 and 208 feet per mile respectively. Spawn Creek has the highest gradient, 394 feet per mile. The gradient in lower Logan River is about 35 feet per mile.

Costley (1941) states that the Logan River covers an area of 133.96 surface acres. Brown (1935) reports an average depth of 0.74 feet and attributes the low depth figure to an almost total lack of pools.

²Utah Fish and Game Department, Wildlife Management Institute, Utah State Agricultural College and U. S. Fish and Wildlife Service cooperating.

³Letter from Dr. Robert R. Miller, Associate Curator of Fishes, Univ. of Mich., Ann Arbor, to Dr. W. F. Sigler, Wildlife Mgt. Dept., Utah State Agric. College, Logan. February 18, 1949.

This, in his opinion, is probably the most undesirable situation existing from the standpoint of fish production. In this study, the average width of Beaver Creek was 9.8 feet while the corresponding mean depth was 1.8 feet. These figures are based upon 120 measurements taken during 1949. The average daily discharge of 247 cubic feet per second for Logan River is based upon the records of three seasons (1946-1949).

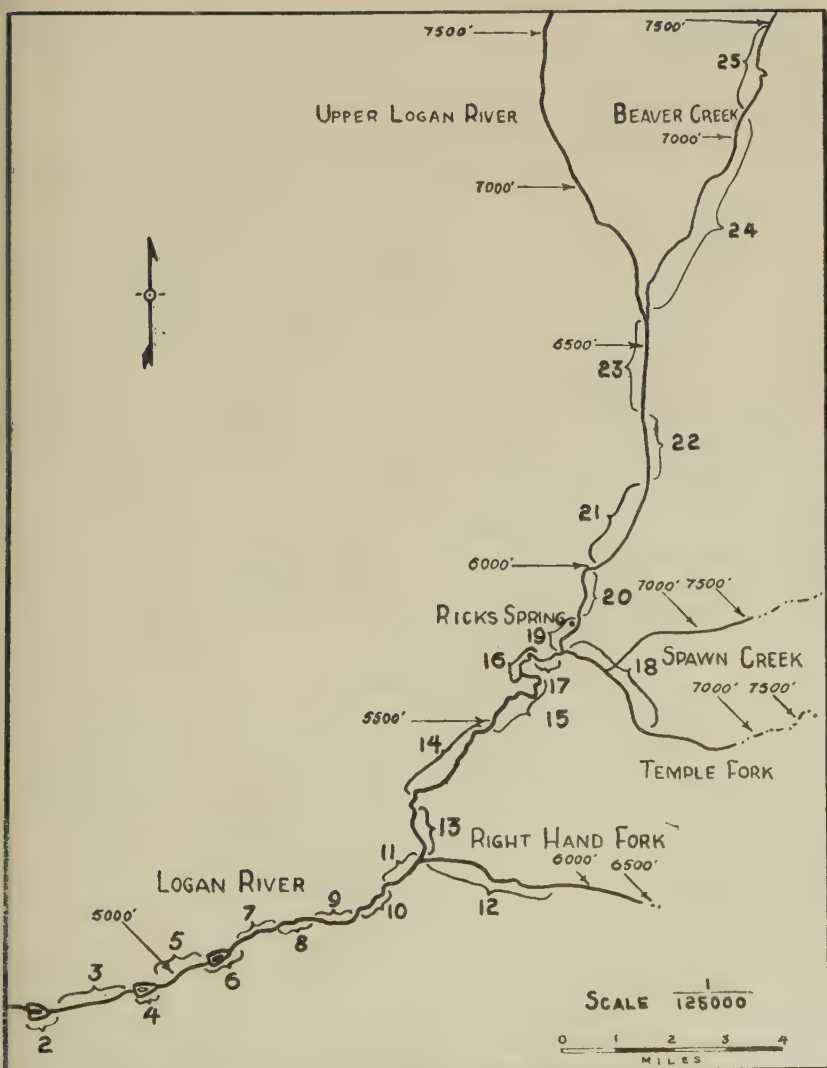


FIGURE 1.—Logan River in the vicinity of the study area.

Spring runoff was especially high during the months of May and June when the average daily discharge was 717 and 612 cubic feet per second or approximately 3 times the average monthly discharge. Brown (1935) lists the average volume in cubic feet per second as 3.27 for Beaver Creek, and the average velocity as 1.29 feet per second. He also concludes that 60 percent of the Logan River flow comes from above Temple Fork.

The stream bottom is composed of rubble and large gravel in most of the study area. Suitable spawning sites are present in Spawn Creek. In Beaver Creek, spawning areas are present in the lower ends of small pools which on the average are 20 to 30 feet apart.

MATERIALS AND METHODS

The study of the Logan River cutthroat trout was based on a total of 306 specimens collected with a portable electrical shocking machine powered by a 700-watt, 220-volt, alternating-current generator. Throughout 1948 and 1949 a total of 44 shocking operations were conducted. During 1948 the total number of samples was 16, and during 1949 the number was increased to 28. Shocking for the 1949 season covered the period from March 3 to November 19. The fish mortality, which never exceeded 2 percent, is attributed to handling rather than to electric shock. Thoreson (1949) repeatedly shocked 48 cutthroat trout at the time of capture, then held them for a period of 60 days without mortality. On July 14, 1949 a similar experiment was conducted with 10 brown trout. They were held for 51 days without mortality.

Unless otherwise specified, standard-length measurements are used throughout the study. Length conversion factors for 305 fish, sexes combined, ranging from 40 to 290 millimeters in total length, were computed as follows: standard length = $0.8367 \times$ total length, and total length = $1.1950 \times$ standard length.

Scale samples were taken from the left side of the fish above the lateral line and below the anterior margin of the dorsal fin. Eight to ten scales from each fish were mounted in the gelatin-glycerin medium and examined on a table-model microprojector with a magnification of 50x.

The food habits of the cutthroat trout in Logan River were studied in essentially the same manner as that employed by Sigler (1949). Intestinal contents were not recorded because they contained almost completely digested food.

FISH POPULATIONS

Use of the electric shocking machine provided information on fish populations. The estimated efficiency recovery at different points on the stream ranged from nearly 100 percent to not more than 25 percent. The degree of recovery depended on many variables, such as water velocity and volume, overhanging banks, and brushy stream areas which

hamper the picking up of fish. Small fish are easily overlooked in areas of high gradient and may escape or be washed through the mesh of the blocking seines placed at the lower end of the area being shocked.

The cutthroat trout in Logan River drainage show a strong tendency to remain in the smaller streams with steeper gradients. Only an occasional fish has been recovered in areas below Right Hand Fork. On two different surveys, 15 and 20 fish respectively were removed from two different one-tenth mile sections on Right Hand Fork. Large numbers of cutthroat trout were in the mouth of Temple Fork. Ninety percent of these fish were less than 7 inches in total length. The fish above Section 23 are predominantly cutthroat trout and the number per one-tenth mile often exceeded 150.

During 1949 a total of 142 cutthroat trout taken by electric shocking machine were marked with a circular tag in the lower jaw, then measured and released for future recovery. Fifteen fish or 10.6 percent were recaptured. None had moved out of the one-tenth-mile shocking station where they had been released.

In 1948 the cutthroat trout comprised 24 percent of the total Logan River catch by anglers (Thoreson, MS), and 31.5 per cent (Pechacek, MS) in 1949. In the upper Logan River the cutthroat is the principal game fish. The brown trout is confined for the most part to the lower areas of the Logan River. One exception to this distributional pattern is noted in Spawn Creek. In this area, brown trout less than 7 inches in length predominate with numbers as great as 29 per one-tenth mile. The rainbow trout is stocked throughout the length of the Logan River. The eastern brook trout which occurs in small numbers is limited to the area above Section 23, and is probably not an important competitor of the cutthroat trout.

The mountain whitefish is present in varying numbers in the deep pools from about 1 mile above the upper Logan River junction to below the first dam of Logan River (Section 2). The upper snake muddler is present in large numbers in the lower Logan River. The smallfin redbside shiner is rare.

The numbers of cutthroat trout and the weight per acre were estimated on the basis of four samples totaling 476 yards of stream. These four stations were assumed to be representative of 16.9 miles of channel above the juncture of Temple Fork. Of the total weight of 55.5 pounds per acre, 43.6 pounds were cutthroat trout. A calculated minimum of 565 fish per mile was estimated from these four samples. A comparison of Logan River with other trout waters where surveys of standing crops have been made indicates that the cutthroat waters of this drainage have a weight and size composition of fish somewhat similar to a number of other streams. Smith, Johnson, and Hiner (1949) list weight of trout in streams of the Minnesota north shore of Lake Superior as ranging from 101.2 pounds per acre in French River down to as few as 2.85 pounds in Manitou River. They found

about 44 pounds per acre of trout in Root River, although this represented only 17 percent of the total of 251.1 pounds of fish recovered in that stream. Hoover (1938) described similar conditions among fish populations in eastern brook-trout streams in New Hampshire.

Although Logan River supports a standing crop of fish about equal to that of some other good trout streams, the number of forage fish here is negligible. No upper snake muddlers, the principal forage fish in lower Logan River, were taken in any of the four stations selected for the study of the standing crop. In no instance were muddlers recovered above Station 24, although from 30 to 50 per mile have been taken from that point down to Station 18.

AGE AND RATE OF GROWTH

A total of 49 young fish and 234 fish one or more years old was used in the age and growth studies. Although scale measurements were taken of all fish, only those having one or more annuli were used in the summary of the average calculated growth. The fish from the

TABLE 1.—*The body-scale ratio of 284 Logan River cutthroat trout—based on 10-millimeter standard length intervals.*

Average standard length	Average scale radius	Body-scale ratio	Number of fish
44.1	6.2	7.11	8
64.4	10.4	6.19	10
74.0	14.1	5.27	12
86.1	16.6	5.19	15
96.6	17.1	5.65	23
105.6	18.6	5.66	20
115.4	19.9	5.80	19
125.7	21.0	5.99	26
135.5	25.7	5.27	28
145.2	23.1	6.29	29
155.8	23.4	6.66	15
165.3	25.8	6.41	20
175.8	28.5	6.17	9
185.5	28.9	6.42	13
195.2	28.7	6.80	14
203.5	29.6	6.88	8
219.6	31.0	7.08	3
224.8	28.6	7.86	6
236.5	34.0	6.96	2
243.0	37.0	6.57	2
255.0	33.0	7.72	2
Weighted Average.....		6.08	

1948 and 1949 collections were placed in 10-millimeter length classes with sexes combined. The body-scale ratio was curvilinear (Table 1) with the body growing proportionately faster than the scale. This relationship was described by the equation:

$$L = cS^n$$

where c and n are constants. Solution for the constants resulted in the equation:

$$\text{Log } L = 0.5392 - 1.2006 \text{ Log } S$$

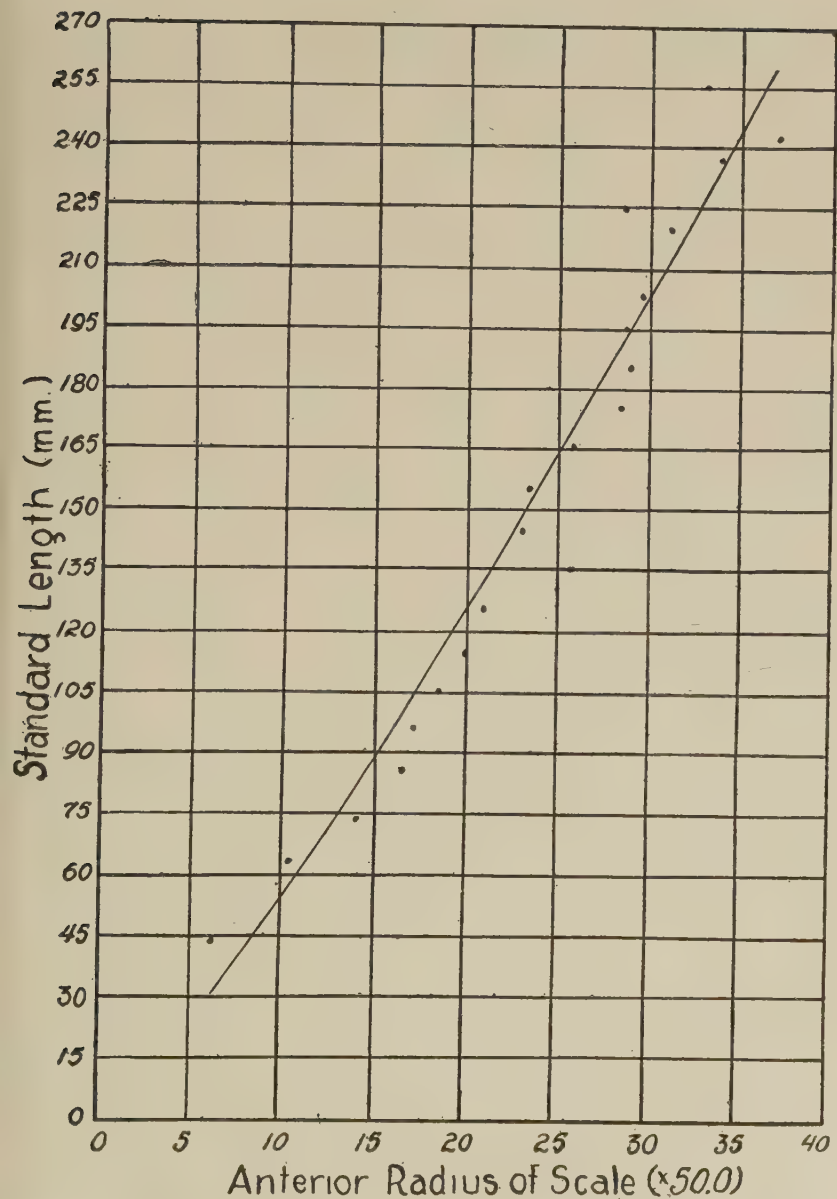


FIGURE 2.—Body-scale relationship of 284 Logan River cutthroat trout. Points that indicate the actual values are based on the averages shown in Table 1.

The closeness of fit between actual and calculated data is apparent (Figure 2). The 10-millimeter length groups at either end of the theoretical curve show the greatest disagreement, but are based on relatively few fish. Less than 2 percent of the fish were eliminated from the final calculations because scale readings were questionable. Computation of growth was made with a nomograph similar to that described by Hile (1950).

It is at once evident from the summary of ages that few fish attain the age group III (Table 2). The relatively small sample of fish precluded determining whether or not a dominant year class existed. An examination of the scales, taken throughout 1948 and 1949, revealed that annuli were usually formed during the first 2 weeks in October. A fish spawned in 1948 with one annulus laid down that fall would be in its second year of life the following summer. Hile (1941) concluded that the interpretation of the annulus as a year mark may be demonstrated in part by a correlation between size and age. As the length of the Logan River cutthroat trout increased there was a corresponding increase in the number of annuli. However, individual fish older than 1 year could not be placed in the proper age classes by reference to length because there was a wide variation in size.

Although the time of annulus formation was determined, some difficulty was encountered when fish of the same size had either one or no annulus. A similar situation was encountered by Robertson (1947) who concluded that some young cutthroat trout failed to reach the length at which scales are formed before the growth check of the first winter. Needham and Vestal (1938), in a study of the golden trout in two high Sierra lakes, found some trout, 1 year old, that had no growth check, although the fish were recovered after an entire winter in the lake. They believed that scales were not formed until the fish reached their second summer. No fish taken in the Logan River study area passed into the first winter without forming scales. Nevertheless, some scales from a series of small cutthroat trout taken October 1, 1949, had not formed an annulus, in spite of having passed through the period during which the annulus ordinarily is laid down. No annulus was found in fish with less than seven to nine circuli on their scales. Robertson (1947) observed a series of six to eleven completed circuli before the first growth check.

It is apparent that a small percentage of the fish may actually be a year older than is indicated. This fact produces no great error in calculated rate of growth, since fish which fail to form a growth check are spawned quite late, and thus have a comparatively short first growing season of 1 to 2 months.

Of the many examples pointing to time of annulus formation three may be mentioned. A 165-millimeter cutthroat trout, taken on October 9, 1948, had two annuli with the one for the current year at the mar-

gin of the scale. A 181-millimeter fish taken May 31, 1948, had two annuli and one complete circulus outside the last annulus. A 229-millimeter fish of age group III captured at the same time had two circuli outside the last annulus.

AGE AND LENGTH AT MATURITY

During 1949 a total of 109 fish was examined for sexual development. All fish 2 or more years old were mature. The standard-length class 121 to 130 millimeters contained six adult males (average total length 5.8 inches). This group, which contained a total of 26 fish, also included eight sub-adult females. One adult male of 120 millimeters

TABLE 2.—*Summary of the average calculated standard lengths in millimeters and increments of length for each year of life in the Logan River cutthroat trout collected during 1948 and 1949.*

Age group and item	Number of fish	Length at capture	Calculated length at each annulus		
			1	2	3
I.....	152	127	90	.....	.....
II.....	73	183	81	151	.....
III.....	9	235	68	131	202
Grand averages and total...	234	.....	86	149	202
Increments of growth.....	.....	.....	86	63	53

was noted. The smallest adult female was 134 millimeters in length. Males matured faster than the females in every instance. Very few mature females were present in the length classes below 180 millimeters. Adult females were usually slightly longer than the 7-inch legal limit (178 millimeters), but a number of adult males did not exceed this size. In age group I, 34 percent of the fish were mature. In age group II, 100 and 92 percent respectively of the males and females had attained maturity.

REPRODUCTION AND SEX RATIO

Some information on the period of spawning has been provided by specimens collected in the course of shocking operations. During the spawning season the gonads were classified as immature, ripe, or spent. Throughout the balance of the year those fish which had no visible eggs or milt were classified as immature.

During 1948 most of the females were ripe, that is, the eggs could be removed by stripping, before June 18. In 1949 the ripe period was found to range from April 12 to August 16 although most fish taken after July 19 were spent. Smith (1941) listed the spawning dates as May 4 to May 15 (1940) for the cutthroat trout taken from Heenan

Lake and transported to Convict Creek for observations. The black-spotted, or Lahontan cutthroat trout (*Salmo clarki henshawi*) were reported spawning in Beaver Creek, Elko County, Nevada, on April 25 (1949), yet the same species from Walker Lake, Nevada, were stripped a number of times during the period May 15 to May 24 (1948).⁴ The spawning period of the cutthroat trout in the Logan River drainage appears to cover a period of nearly 4 months.

Most of the gravid females in Logan River were found in areas where the total flow did not exceed 4 second-feet. The adult females ranged in size from 11 inches total length downward. Walker Lake cutthroat trout spawned in streams in which the depth varied from 3 to 6 inches and the total flow fluctuated between 5 and 8 second-feet.

An attempt was made to determine sex of all fish retained for the study but it was found impossible to sex any fish under 60 millimeters in standard length. Nearly all fish above 90 millimeters could be sexed with confidence but from external characteristics only in the spawn season. The sex ratio of 241 cutthroat trout from 35 collections was 111 females per 100 males.

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship of the Logan River cutthroat trout can be described by the following logarithmic equation:

$$\text{Log } W = -4.3620 + 2.8253 \text{ Log } L$$

where L equals standard length in millimeters and W equals weight in grams. It would thus appear that the trout grow slightly slimmer as they increase in length in contrast to most other observations.

The coefficient of condition or K factor is a commonly used measure of plumpness of fish. It is determined by the formula:

$$K = \frac{W \times 10^5}{L^3}$$

where W equals weight in grams and L equals length in millimeters. The average value of K for 241 Logan River cutthroat trout was 1.819. Schneider and Griffiths (1943) reported an average K of 1.30 for 214 pond-reared cutthroat trout in western Oregon. Variation of condition of cutthroat trout within the 2 years of the study was negligible. However, males are slightly heavier than females. The K factor tended to decrease in the Logan River cutthroat with an increase in age and size as would be expected from the analysis of length-weight ratios.

⁴Letter from T. J. Trelease, Nevada Fish and Game Commission, Reno, to the author, dated March 27, 1950.

TABLE 3.—Food of the cutthroat trout from the Logan River, Utah, in 1948 expressed as percentages of frequencies of occurrence and percentages of total volume of food items.

Item	Month of collection				
	May	June	July	August	October
Number of stomachs.....	14	17	35	16	3
Number containing food.....	13	17	34	16	2
Percentage containing food.....	93	100	97	100	66.7
Total volume food (cubic centimeters).....	13.57	15.54	34.30	10.33	0.5
Total length (millimeters)					
Range.....	109—266	90—262	110—290	118—249	185—198
Mean.....	194.5	188.1	180.7	156.4	190.3
Insects.....	Occurrence Volume	Occurrence Volume	Occurrence Volume	Occurrence Volume	Occurrence Volume
Undetermined.....	100.0 97.6	100.0 52.6	100.0 100.0	100.0 100.0	100.0 100.0
Determined.....	61.5 23.4	58.8 14.5	82.4 30.2	68.8 36.3	.....
Orthoptera.....	100.0 74.2	100.0 38.1	100.0 69.8	100.0 63.7	100.0 100.0
Plecoptera.....	.....	5.9 4.5	20.6 6.6	6.2 0.2	.....
Odonata.....	.....	76.5 4.3	14.7 3.1	43.7 7.4	.....
Ephemeroptera.....	92.3 12.2	82.4 7.1	2.9 0.1	.....	.....
Hemiptera.....	23.1 0.9	.....	79.4 30.8	100.0 34.8	.....
Neuroptera.....	.....	.....	5.9 0.1	.....	.....
Trichoptera.....	61.5 27.7	64.7 15.1	52.9 11.0	68.8 15.5	.....
Diptera.....	8.5 20.0	58.8 4.5	55.9 8.1	18.7 5.6	100.0 100.0
Coleoptera.....	38.5 10.6	23.5 1.0	32.3 4.4	.....	.....
Hymenoptera.....	53.8 2.8	47.1 1.4	50.0 5.4	6.2 0.2	.....
Arachnoidea.....	15.4 2.4	.....	.....	.....	.....
Araneae.....	15.4 2.4	.....	.....	.....	.....
Annelida.....	.....	23.5 14.3	.....	.....	.....
Fish.....	.....	5.9 33.1	.....	.....	.....
Cutthroat trout.....	.....	5.9 33.1	.....	.....	.....

TABLE 4.—*Food of the cutthroat trout from the Logan River, Utah, in 1949 expressed as percentages of frequencies of occurrence and percentage of total volume of food items.*

Item	Month of collection					
	March	April	May	June	August	October
Number of stomachs.....	8	14	9	42	6	71
Number containing food.....	8	13	8	42	6	69
Percent containing food.....	100.0	93.0	89.0	100.0	100.0	97.0
Total volume food (cubic centimeters)	3.41	3.11	10.53	20.23	3.71	12.72
Total length (millimeters)						
Range.....	126—294	83—229	88—208	91—272	125—218	75—257
Mean.....	181.7	138.6	147.9	177.5	188.2	146.6
Insects.....	Occurrence Volume	Occurrence Volume	Occurrence Volume	Occurrence Volume	Occurrence Volume	Occurrence Volume
Undetermined insects.....	100.0 100.0	100.0 96.1	100.0 50.6	100.0 99.2	100.0 100.0	100.0 92.6
Determined insects.....	75.0 17.0	69.2 35.0	75.0 10.9	83.3 35.0	83.3 24.8	26.1 14.3
Colembola.....	87.5 83.0	100.0 61.1	100.0 39.7	95.2 64.2	100.0 75.2	100.0 78.3
Orthoptera.....						1.4 0.2
Plecoptera.....	50.0 12.9	69.2 6.2	25.0 0.4	7.1 0.7	33.3 2.7	5.8 2.0
Odonata.....						33.3 4.1
Ephemeroptera.....						4.3 2.3
Hemiptera.....	75.0 10.0	38.5 9.7	12.5 1.9	81.0 27.5	100.0 35.3	17.4 4.3
Neuroptera.....		7.7 0.6	62.5 2.1	2.4 0.1		11.6 1.7
Trichoptera.....						1.4 0.1
Lepidoptera.....	75.0 50.2	76.9 28.6	100.0 17.7	79.4 13.5	66.7 30.2	50.7 23.7
Diptera.....	25.0 7.0	61.5 14.1	87.5 6.2	2.4 0.4	16.7 0.8	36.2 6.7
Coleoptera.....	12.5 2.9	15.4 1.9	12.5 11.4	40.5 3.6		42.0 7.2
Hymenoptera.....				23.8 3.7	33.3 6.2	45.0 26.0
Crustacea.....				59.5 14.7		2.9 0.1
Malacostraca.....						1.4 0.1
Cladocera.....						1.4 trace
Arachnida.....		7.7 3.9		2.4 0.8		2.9 0.2
Aranae.....		7.7 3.9		2.4 0.8		2.9 0.2
Diplopoda.....						1.4 1.0
Annelida.....						5.8 1.4
Fish.....						
Cutthroat trout.....		12.5 1.0				
Fish eggs.....		12.5 48.4				
Plant material.....		12.5 48.4				
						2.9 0.3
						5.8 4.4

FOOD HABITS

Very few studies of the food habits of the cutthroat trout have been published. Hazzard and Madsen (1933) concluded that trout from rather similar streams, but in different regions, show a high degree of variation in the items consumed. Muttkowski (1925), in a food habits study of this species in Yellowstone National Park, discovered that stoneflies comprised 90 percent of their diet, while mayflies were second in importance. Calhoun (1944), in a study of the black-spotted trout in two Sierra Nevada lakes, determined that the most important food was immature chironomids. He noted an almost complete absence in the trout diet of a small minnow which was abundant in the shallows around the lake.

The Logan River cutthroat trout had a diet composed almost entirely of insects. The bulk of the insects were Ephemeroptera and Trichoptera. Fish were the only vertebrate species taken, and the two occurrences of fish noted were cutthroat trout. Absence of a suitable forage fish in the headwaters of the Logan River may be partly responsible for the comparatively small size of the cutthroat trout. The amount of plant material was negligible. Almost no fish eggs entered the diet. Over the 2-year study period, material has been gathered during the 7 months of March through October. No data were taken in September. Many of the summer months were repeated the second year, so the food habits are presented for 11 months during the 2-year period. Inasmuch as the Logan River cutthroat trout fed principally on insects, a study of the orders taken provides information on preference. An almost complete absence of the larger forms of food eliminates the necessity of breaking down the food presentation on an age or length basis (Tables 3 and 4).

ACKNOWLEDGMENTS

Special thanks are due Dr. William F. Sigler, Utah State Agricultural College, for supervision of the field work and criticism of the manuscript. Dr. George Kelker of the Wildlife Management Department, and Dr. Jessop B. Low, Leader, Utah Cooperative Wildlife Research Unit, made needed equipment available and otherwise assisted at every opportunity. Kindest thanks are due Messrs. Nels A. Thoreson, Louis S. Pechacek, William J. McConnell, Albert F. Regenthal, Gordon Zorb, and Albin R. Essbach for their help in the field work. Dr. J. Sedley Stanford and Mr. David McComb of the Zoology Department verified the more difficult insect identifications. To my wife, Rosezella Mae Fleener, for assistance in taking data and for much of the calculating, my sincerest appreciation is given.

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LIFE HISTORY OF THE UTAH SCULPIN, *COTTUS BAIRDI SEMISCABER* (COPE), IN LOGAN RIVER, UTAH¹

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ABSTRACT

The study of the Utah sculpin in Logan River was based on 801 specimens collected from 1949 to March 1951. Fish were collected by use of an electric shocking machine generating 600 watts and 220 volts. Numbers of fish taken were as high as 150 per 0.1 mile of stream. Preferred habitats were areas of coarse gravel and small rocks. Age determination was made from vertebrae and length-frequency distributions indicated that the age determinations were accurate. Determinations of sex were by external observation and were difficult except during the breeding season. Relationship between standard length (millimeters) and weight (grams) is described by the following formula: $W = 4.236 \times 10^{-4} L^{2.900}$

The coefficient of condition (K) increased with length of fish up to 60 millimeters of standard length and then decreased in fish of larger size. The greatest variation in K occurred in fish less than 50 millimeters long. The food consisted almost entirely of aquatic insects, principally Diptera. Ephemeroptera, Plecoptera, and Trichoptera were consumed in almost equal numbers. Food availability and preference were determined from bottom samples of the river. Competition with trout for food is minimized by the fact that the sculpin is a bottom feeder and rainbow and brown trout are primarily surface feeders. Predation of trout eggs by the sculpin was very slight.

INTRODUCTION

The study of the Utah sculpin, *Cottus bairdi semiscaber* (Cope), on Logan River, Utah, was made to determine its relationship to game fish. Economically the sculpin is of little significance and in many areas it is considered a nuisance. Simon (1946) stated that transfer of the species across the watershed divide is forbidden by the Wyoming Game and Fish Department, even though the sculpins are native to most mountain streams. This restriction was put in force because they have been carelessly distributed by bait fishermen.

Studies of food habits of the sculpin have been made by Koster (1937), Pearse (1918), and others. Koster also described the relationship of the sculpin to game fish. Smith (1922) and Simon and Brown (1943) have published detailed work on the spawning of the sculpin in Michigan and some spring creeks near Jackson, Wyoming, respectively. The present work was carried on from 1949 to March, 1951 to supplement existing knowledge of this fish.

THE LOGAN RIVER

The Logan River lies largely in the Cache National Forest but the make-up of the drainage area is varied. The formations of the drainage which comprise part of the Bear River Range consist principally of dolomitic limestone and calcareous sandstone. Weathering of these rocks is in part responsible for the alkalinity of the river. The study area extended from a point 10 miles downstream from the Idaho state line to a point one-half mile downstream from the mouth of Logan Canyon. This stretch has few deep pools and the average depth of the channel during July, August, and September is less than 3 feet. The stream bottom consists of silt, coarse gravel, rocks, and boulders in varying combinations. The principal sources of water are springs and melting snows and from April to October the average water velocity is 2.6 feet per second. The source of water and the many shaded areas maintain low water temperatures during summer months. Brown (1935) reported that the maximum water temperature for the same period was 80° F. and the minimum 49° F. During 1950 the summer water temperatures in the study area varied from a minimum of 48° F. in July to a maximum of 55° F. in August. Air temperatures during this same period ranged from 60° to 72° F.

There are four native fish in the river proper: mountain whitefish, *Prosopium williamsoni* (Girard); cutthroat trout, *Salmo clarki* Richardson; Utah sculpin; and rarely the small fin redside shiner, *Richardsonius balteatus hydrophlox* (Cope). The three other species which occur were introduced. These fish are the brown trout, *Salmo trutta fario* Linnaeus; eastern brook trout, *Salvelinus fontinalis fontinalis* (Mitchill); and coast rainbow trout, *Salmo gairdneri irideus* Gibbons. Two species of sculpins are found in the Logan River drainage. Miller and Sigler (1950) separated the Utah sculpin from Belding's sculpin *Cottus beldingi* Eigenmann and Eigenmann by the presence of two or more preopercular spines on the former in contrast to one or none on the latter.

HABITAT AND RANGE OF THE SCULPINS

The Utah sculpin is widely distributed in the Rocky Mountain area, particularly in the Upper Snake River and Bonneville system. It is most abundant in areas where the stream bottom is composed primarily of coarse gravel and small rocks. Smith (1922) noted that the preferred habitats in Michigan were small streams with stony and gravelly bottoms. Simon and Brown (1943) investigating the spawning habits of the sculpin in Wyoming stated that the bottom of the stream was of coarse gravel, mingled with large rocks. In choosing nesting sites, the fish ignores the velocity of the water and uses rocks occurring in either rapid or slow currents. Few fish were collected from silted areas. Most collections were from areas with bottoms of coarse gravel

and small rock. Water depths in apparently preferred habitats ranged from 6 inches to 3 feet during the months of July to September. No sculpins were collected from Logan River at altitudes greater than 7,000 feet.

FOOD HABITS

The study of food habits of the Utah sculpin was undertaken in essentially the same manner as that employed by Sigler (1949). Stomachs were removed from 275 fish, rolled in strips of cheesecloth with a label bearing the serial number of the fish, and preserved in a solution of 10 percent formalin. Intestines were not saved because the food items in them were almost completely digested. Tabulations of food items occurring in the stomachs are presented as percentages of occurrence, number, and volume (Table 1). It is believed that these tabulations give a representative picture of the dietary habits of the sculpin in Logan River. The results are shown for three periods in 1949: January, February, and March; June, July, and August; and September and October.

Although sculpins are reputed to prey on eggs and young of the trout family, very little work has been published to support this assumption. Koster (1937) who analyzed 30 stomachs of sculpins from Cayuga Lake, New York, and vicinity found only two stomachs containing trout eggs. Surber (1920) stated that little evidence exists of predation of trout eggs or young trout by the sculpin. Koster (1937) reported that three orders of aquatic insects—Ephemeroptera, Diptera, and Trichoptera—formed the bulk of the food in sculpin stomachs. The diet of the sculpin in Logan River followed the trends reported in other investigations and consisted primarily of insects with plant material, fish, stones, and wood occurring rarely. Most of the aquatic insects were Diptera. Although the total number of insects consumed per individual was nearly constant over the three periods, the average was slightly higher during the first period than in the second and third periods. The volume of food taken varied little and few of the stomachs analyzed were full. The full stomachs contained either fish or the larger insect forms such as *Tipula* larvae or Plecoptera larvae.

All of the fish eaten were young sculpins (Table 1). A total of three trout eggs and two muddler eggs were taken, but they constituted only a very small percentage of the total food consumed. Since the trout eggs may have washed out of the nest, their loss was probably not detrimental to reproduction.

Species of Diptera occurred more often in the first period than in the second or third periods. The lower percentage of volume in comparison to the percentage of numbers is due in part to the small size of *Chironomus* and *Simulium*. Many of the stomachs analyzed during this period contained *Chironomus* larvae only, with total individual counts sometimes as high as 40. *Tanytarsus* was taken occasionally

TABLE 1.—Food of Utah sculpin in Logan River, expressed as percentage of frequencies of occurrence, total volume of food, and total number of food items.

Item	Date of collection						Grand total		
	January, February, March			June, July, August					
	Occ.	Number	Volume	Occ.	Number	Volume	Occ.	Number	Volume
Fish (total).....	2	2	39	2	1	9	1	1	4
<i>Cottus bairdi semiscaber</i>	2	1	39	2	1	9	1	0.2	4
<i>Cottus</i> eggs.....	1	1	Tr				1	0.2	Tr
Trout eggs.....							2	0.6	Tr
Invertebrates (total).....	100	98	61	99	99	91	98	99	96
Diptera (total).....	73	61	45	41	42	14	53	55	17
<i>Chironomus</i>	36	47	5	32	14	3	46	48	13
<i>Tipula</i>	41	14	40	3	1	3	6	1	3
<i>Simulium</i>				12	27	7	7	4	0.5
<i>Tanytarsus</i>							1	2	0.5
Trichoptera (total).....	34	24	3	41	17	9	15	9	5
<i>Hydropsyche</i>	16	16	1	24	11	6	6	2	1
<i>Brachycentrus</i>				4	1	2	3	1	Tr
<i>Platyphlaz</i>				3	1	Tr	4	6	4
<i>Glossosoma</i>							2	Tr	Tr
Undetermined.....	22	8	2	15	4	1	1	Tr	Tr
Ephemeroptera (total).....	20	7	3	47	26	2	30	19	25
<i>Iron longimanus</i>				6	2	10	1	1	1
<i>Ephemerella grandis</i>				13	6	1	6	2	6
<i>Ephemerella daddsi</i>				3	Tr	Tr	5	1	8
<i>Ephemerella coloradensis</i>				1	Tr				
<i>Rithrogena elegantula</i>							2	4	
<i>Rithrogena minus</i>				1	Tr	Tr			
Undetermined.....	20	7	3	31	18	13	18	11	8
Plecoptera (total).....	26	6	10	40	13	21	43	13	47
<i>Pteronarcella badia</i>				8	2	6	3	1	1
<i>Acronuria pacifica</i>	11	2	3	21	6	14	24	5	38
<i>Isoperla</i> spp.....							1	Tr	Tr
Undetermined.....	15	4	7	14	5	1	16	7	8
Coleoptera.....				2	Tr	Tr	6	1	1
Oligochaeta.....				1	Tr	Tr			
Miscellaneous.....	2	Tr	Tr	7	Tr	Tr	11	Tr	Tr
Number of stomachs.....	74			104			97		275
Cubic centimeters of food.....	23.2			13.5			14.4		51.1
Total number of food items.....	360			571			500		1,431
Total length of fish (in millimeters)									
Range.....	32—130			60—134			42—120		32—134
Mean.....	95.35			98.12			91.84		95.45

Tr indicates trace.

with the percentage being highest during September and October. *Simulium* were eaten by few fish but numbered up to 50 or more when present in the stomach contents.

Ephemeroptera ranked second in occurrence and in number. Many were determined to order only because they were in an advanced stage of digestion. *Ephemerella grandis* was taken more frequently than other members of this order. The highest numbers were consumed during June, July, and August. *Ephemerella doddsi* was next in importance, followed by *Iron longimanus* and *Ephemerella coloradensis*. Species of *Rithrogena* were taken only occasionally.

More Plecoptera were consumed during the third period than during either the first or second. *Acroneuria pacifica* was the most abundant species consumed, and stomachs containing only a few of them were distended from the large size of the insect. Aside from *Tipula* larvae, species of Plecoptera were the largest insects in the diet. *Isoperl*a was taken occasionally. *Pteronarcella badia* accounted for about one-eighth of the total volume of Plecoptera eaten.

Trichoptera were eaten case and all by many sculpins. *Brachycentrus* occurred in greater numbers than did *Neothremma* (*Platyphylax*). *Hydropsyche* was present more often than any other species in the order. *Brachycentrus*, *Neothremma*, and *Glossosoma* had no occurrence during the period of January, February, and March. Coleoptera and Oligochaeta were rare. Coleoptera were found only in the adult stages during the months of January and February. Oligochaeta occurred in one stomach during the period of June, July, and August. Miscellaneous items consisted of stones, wood, and plant material. Plant material was from both higher plants and filamentous algae.

Preference in relation to availability of food was determined by comparing food taken by the sculpin with organisms occurring in bottom samples of the river. Diptera, Ephemeroptera, Plecoptera, and Trichoptera in that order were the aquatic insects most available. Food items designated in this study as preferred food were Diptera, Plecoptera, Ephemeroptera, and Trichoptera in that order. This study apparently shows that the sculpin is a potential competitor for food with game fish. Even though food is scarce during the winter months there is little predation by the sculpin on trout. Competition for food is minimized by the fact that the trout is primarily a surface feeder whereas the sculpin is almost wholly a bottom feeder.

AGE AND GROWTH

The determination of age in the Utah sculpin was based on the number of annuli in the centrum of the vertebra. The annuli in the centra are in the nature of dense calcifications that increase in number with an increase in the age of the fish. If these rings are laid down annually, the aging technique is a valid one. Hooper (1949) in his age

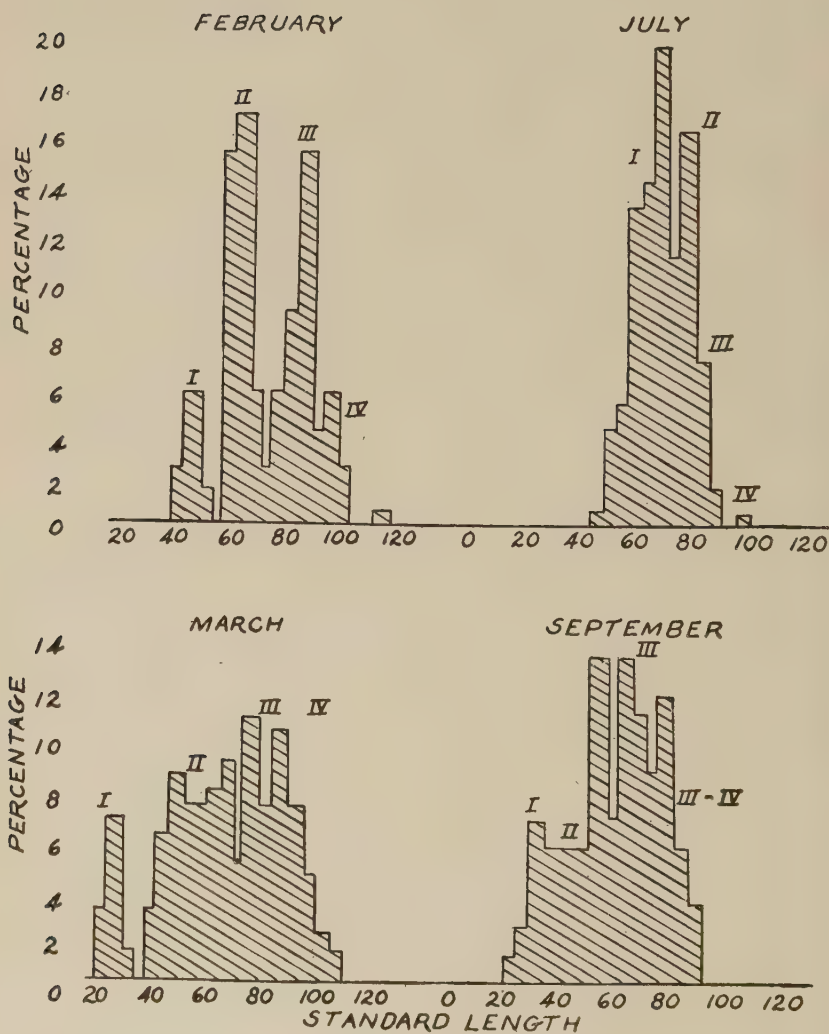


FIGURE 1.—Length frequencies (standard length by 5-millimeter intervals) of sculpins in four months of 1949 and 1950. Frequencies are shown as percentages of the total number of fish in individual collections.

analysis of *Schilbeodes* found that estimates of age from length frequencies and the numbers of dark bands in the centra of the vertebra were in agreement. Lewis (1949) compared aging from vertebrae and scales on *Carpio verifer* and found that the two techniques corresponded closely. Appelget and Smith (1951) showed that the number of rings formed on the vertebrae of channel catfish of known age in all cases corresponded to the actual age of the fish.

Annuli, as defined in this study, are dark, heavy, translucent bands indented slightly into the centra. These bands alternate with white, broader opaque ones. Winter growth, represented by dark bands, is contrasted with the white bands of summer growth. The fact that true annuli are indented into the centrum is of assistance in differentiating true from false annuli. Since intervertebral cartilage masks those annuli on the edge of the centra and a transparent membrane covers the bone surface in the cone of the centra, it is difficult to see all annuli unless both the cartilage and membrane are removed. Accessory marks cause some confusion but are usually fainter than the true winter bands. Often, accessory bands are found deep in the center of the centrum or very close to a true winter band. Checks in those positions are distinguished easily from the true marks. Each annulus was considered an indicator of age since vertebrae of larger fish show more annuli than smaller ones. Rings in older fish were closer together during later years than rings formed early in life. The rapid growth of the second year was indicated by a rather wide white band of summer growth separating the first and second annuli. Difficulty of differentiation between true annuli and accessory marks made annuli on the edge of the centrum hard to read.

Histograms of the length frequencies of 495 fish revealed close agreement between ages estimated from vertebrae and from length-frequency modes (Figure 1). Frequencies, based on 5-millimeter length intervals, indicated considerable overlapping between successive age groups (Table 2).

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship of the sculpin was determined by use of the following formula:

$$W = cL^n, \text{ where}$$

c and n = constants,
 L = standard length in millimeters, and
 W = weight in grams.

This equation has been employed to describe the length-weight relationships of various fishes by numerous authors.

For the Utah sculpin the length-weight equation was determined to be (Table 3, Figure 2):

$$W = 4.236 \times 10^{-4} L^{2.900}.$$

The coefficient of condition of a fish is a measure of plumpness. It is derived by the following formula:

$$K = \frac{W \times 10^5}{L^3}, \text{ where}$$

W = weight in grams, and

L = standard length in millimeters.

In the sculpin, the coefficient of condition varied most in fish shorter than 55 millimeters in standard length. The K factor increased with

TABLE 2.—Age distributions of Utah sculpins in successive 5-millimeter intervals of standard length—sexes combined.

Interval of standard length (millimeters)	Age group					
	0	I	II	III	IV	V
35—39	2					
40—44	10					
45—49	1	4				
50—54	1	7	1			
55—59		19	7	1		
60—64		9	25			
65—69		6	31	7		
70—74		8	36	16	2	
75—79		3	28	22	2	
80—84		1	16	21	3	
85—89			18	17	5	
90—94			4	21	4	
95—99			3	12	8	2
100—104				5	12	
105—109				1		2
110—114					1	
115—119					2	1
120—124						
125—129						1

TABLE 3.—Length-weight relationship of the Utah sculpin in Logan River, Utah—expressed for successive 5-millimeter intervals.

Interval of standard length (millimeters)	Number of fish	Empirical weight (grams)	Calculated weight ¹ (grams)	Mean K
25—29	5	0.4	0.2	2.57
30—34	3	0.3	0.8	2.71
35—39	10	0.8	1.3	1.78
40—44	19	1.7	1.9	2.47
45—49	22	3.4	2.6	3.78
50—54	21	3.9	4.0	3.31
55—59	27	4.8	5.0	3.21
60—64	46	6.8	6.1	3.35
65—69	52	7.9	8.0	3.08
70—74	62	9.9	10.0	3.11
75—79	83	12.1	12.0	3.04
80—84	57	14.5	14.0	2.95
85—89	72	16.9	16.7	2.89
90—94	36	19.8	19.7	2.83
95—99	40	22.8	23.0	2.76
100—104	26	26.3	27.0	2.72
105—109	10	31.8	31.0	2.94
110—114	3	35.5	35.2	2.81
115—119	5	38.9	41.2	2.62
120—124	1	45.0	45.3	2.90

¹Computed by the formula $W = 4.236 \times 10^{-4} L^2.900$.

the length in fish up to 60 millimeters and decreased in fish from 60 to 125 millimeters long. From a series of fish that had first been weighed with stomachs intact and then with stomachs removed, it was determined that K changed more than 6 percent in many individuals.

DETERMINATION OF SEX AND REPRODUCTION

It is usually difficult to determine the sex of fish by external characteristics. In the sculpin the differentiation is almost impossible except in adult fish. Where sexual features were indefinite in adults, gonads were dissected out to verify external observations. In the breed-

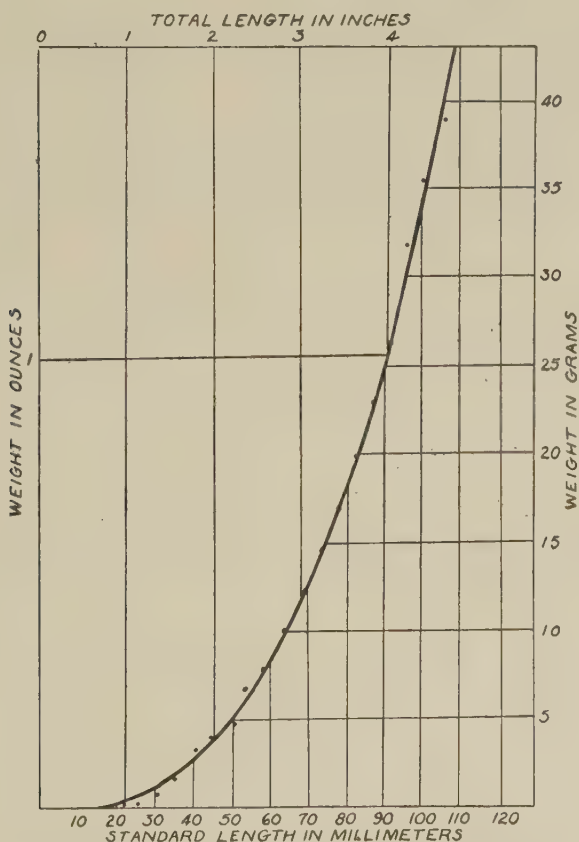


FIGURE 2.—Length-weight relationship of 601 Utah sculpins from Logan River, Utah. Points are based on the average standard lengths and actual weights of Table 2.

ing male, the first dorsal fin is tipped with either a cream or an orange band. This color characteristic rarely occurs in females but when it does occur, sex can be determined only from examination of the gonads.

Ovaries are readily distinguishable from testes in mature sculpins. In cross section ovaries are nearly round while testes are flattened and triangular. Nearly all fish longer than 60 millimeters in standard length could be sexed easily. It was not possible to determine the sex of fish under 35 millimeters in standard length without microscopic examination.

Nesting behavior of the sculpin has been observed by Smith (1922) and Simon and Brown (1943) and is almost identical in Michigan and Wyoming. Preferred nesting habitats of the sculpins in these two areas were similar to those in Logan River. Reproductive activities are carried on in either rapid or slow water and the egg clusters are placed on the under surfaces of rocks. In this study efforts to find nests on the Logan River were unsuccessful. However, examination of sex organs of the female showed that the spawning period was from February to May. This fact suggested that the sculpin is solely a spring spawner in Logan River.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. William F. Sigler for his interest and direction of this study. The suggestions and opinions of Dr. George Hills Kelker, Dr. Jessop B. Low, and Dr. J. S. Stanford were of great value. Appreciation is also extended to Dr. Herbert Ross of the Illinois Natural History Survey for his identification of aquatic insects.

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THE POPULATION AND MOVEMENT OF FISH IN PRICKLEY PEAR CREEK, MONTANA¹

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ABSTRACT

A 2-year study was made on the populations and movements of fish in Prickley Pear Creek, Montana. The most numerous species present were freshwater sculpins, brown trout, rainbow trout, and longnose suckers. The number of brown trout was higher in 1949 than in 1950. Their number in relation to all trout was approximately 60 percent in 1949 and 54 percent in 1950. However, their weight in relation to that of all trout was approximately 74 percent in 1949 and 73 percent in 1950. Rainbow trout made up most of the remainder of the salmonid population. The number of trout in relation to all fish was approximately 79 percent in both years and their weight approximately 58 percent in 1949 and 47 percent in 1950. Weights of the trout remained relatively constant for the sampling periods each year but showed a significant difference between years. Suckers were numerous in the first sampling periods of each year but decreased sharply in the late summer months. The total weights of all fish varied from 58.87 to 241.10 pounds per acre at the different sampling periods. Large numbers of fish were recaptured in the areas where they were tagged. Eleven trout were recovered six times in the same area. Some of the fish moved and of these the general movement was downstream.

INTRODUCTION

An investigation of the population and movements of fish in Prickley Pear Creek, Montana, was begun in the summer of 1949 and carried through 1950. This project was sponsored and financed by the Montana State Fish and Game Department. A similar study was made by Shuck (1945) in Crystal Creek, New York. Smith *et al.* (1949) investigated the populations of some trout streams in Minnesota. Needham and Cramer (1943) observed the movements of trout in Convict Creek, California.

Prickley Pear Creek was selected for study because it was suitable in size, accessible and popular as a fishing stream. It runs in a northeasterly direction over most of its 23-mile course and enters the Missouri River about 6 miles upstream from Craig, Montana. The upper 11 miles traverse a narrow valley, while the lower 12 miles flow largely through a rocky canyon (Figure 1). The creek drains an area of approximately 394 square miles, mostly of grassland with open stands of ponderosa pine. The elevation at the head of Prickley Pear Creek is 4,250 feet above mean sea level and at its mouth is 3,300 feet, with a gradient of approximately

¹Contribution from the Montana Fish and Game Department and Montana State College Agricultural Experiment Station. Project No. MS844, Paper No. 252 Journal Series.

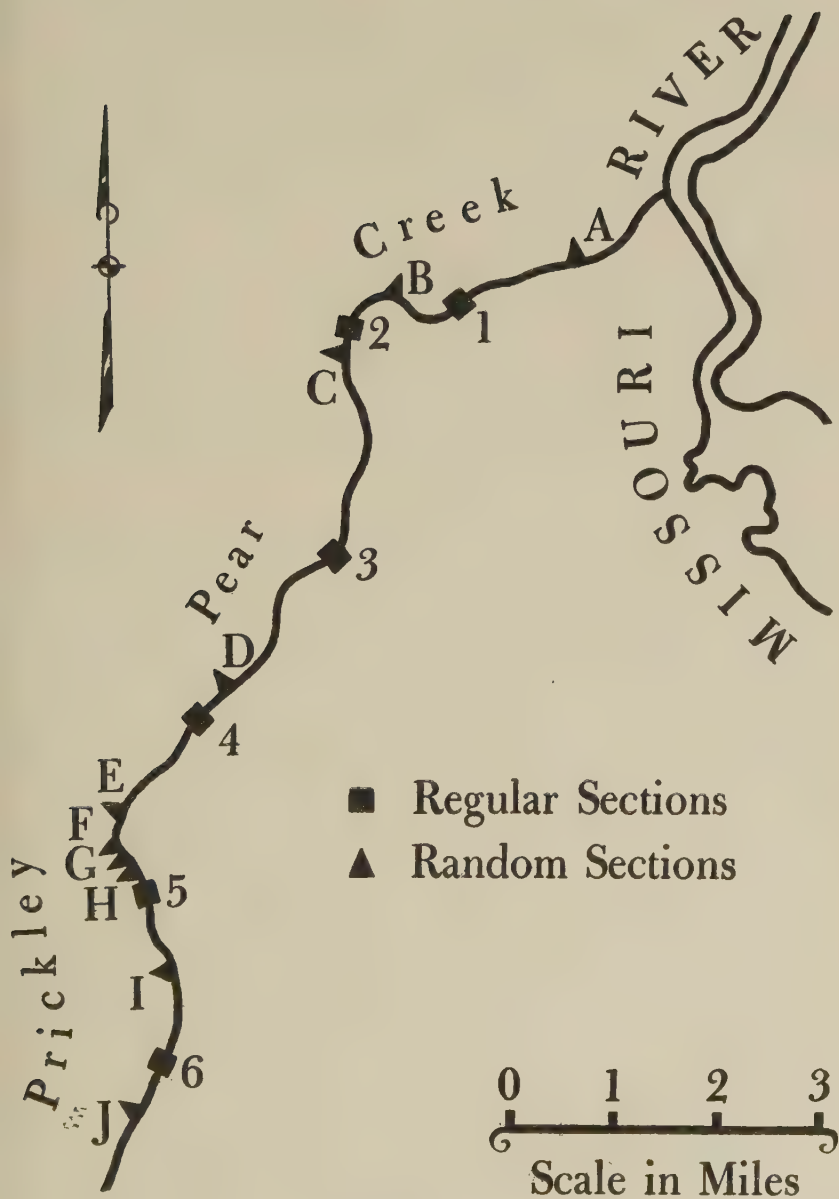


FIGURE 1.—Prickley Pear Creek in vicinity of study area.

41 feet per mile. Most of the land in this drainage is privately owned and is used chiefly for grazing, with very little cultivated land in the valley. Since the entire stream could not be studied intensively, the lower 13 miles were selected. In the study area, stream width varied from 15 to 60 feet and the maximum depths from about 6 inches to 8 feet. There was an average distance of approximately 260 feet between pools with a depth of 3 feet or greater and the riffle areas were mostly shallow and covered with gravel and rubble. The highest temperature recorded was 67°F. and the greatest fluctuation in a 24-hour period was 16°F.

Six representative sections located at more or less equal intervals were selected for special study. Section 1 was established 2.2 road miles from the mouth of the creek and Section 2 was located 1.4 road miles upstream from Section 1. Sections 3, 4, 5, and 6 were established at successive intervals of 2.3 road miles upstream from Section 2. Thick brush, swamp, and absence of a road prevented the establishment of Section 1 at an interval equal to the others. Each section was 600 feet long and its lower boundary was marked by means of a concrete post for later reference.

COLLECTION OF FISH

The electric shock method was used to collect fish. This technique has been employed by a number of workers, notably Haskell (1940) and Shetter (1948). A portable 500-watt alternating-current generator provided the electrical energy and a rheostat and transformer made it possible to secure voltages up to 240. Each section was divided into four 150-foot units which were blocked off with nets and shocked. On the first trip through, a maximum of 160 volts was used to avoid undue injury to large fish and thereafter a maximum of 190 volts was used until no more fish were observed. Stunned fish were caught with dip nets and placed in holding pens which were located in the quietest water available.

Captured fish were anesthetized in a 0.5-percent solution of urethane before weighing and measuring as outlined by Gerking (1949). Total lengths to the nearest 0.1 of an inch and weights to the nearest 0.01 of a pound were taken. Nearly all of the fish captured were either jaw tagged, tagged with a Petersen disk, or fin clipped. They were then allowed to recover in holding pens before being released within the section under study. All trout improperly recorded or identified are classified as "unknown" in population tabulations.

MARKING OF FISH

Strap tags similar to those described by Shetter (1936) and Rounsefell and Kask (1945) were used in marking trout. The serially numbered monel-metal tags used in this study were of two styles (1005 and 18M) and four sizes (1, 3, 4, and 18M) as manufactured by the National Band and Tag Company.

The size of tags and the trout on which they were used are as follows (lengths are approximate):

No. 1 on trout 3.5-5.5 inches total length

No. 3 on trout 5.6-14.0 inches total length

No. 4 on trout 14.1-18.0 inches total length

No. 18M on trout 18.1 inches and over total length.

A tag was clamped around the dentary bone of each fish, then rounded with pliers in order to prevent unnecessary pressure and chafing. Species of fish other than trout were either fin-clipped or tagged with a Petersen disk held in place with a nickel pin just ventral to the dorsal fin.

FISH POPULATIONS

Species of fish present.—The brown trout (*Salmo trutta*) was the predominant salmonid species except during one sampling period when it was exceeded in numbers by rainbow trout (*Salmo gairdneri*). Eastern brook trout (*Salvelinus fontinalis*) were present in small numbers and only one cutthroat trout (*Salmo clarki*) was found. Some hybrid rainbow x cutthroat trout were present but were so difficult to distinguish from the rainbow trout that it was not practical to separate them. They are therefore included with the rainbow trout. The mountain whitefish (*Prosopium williamsoni*) and the western white sucker

TABLE 1.—Shocking periods, inclusive dates, length of period, and average number days since last shocking in Prickley Pear Creek—1949-1950.

Number	Shocking period	Days of shocking period	Average number days since last shocking
	Inclusive dates		
1	June 22 to July 13, 1949.....	22	..
2	August 11-17, 1949.....	7	40
3	September 16-23, 1949.....	8	36
4	November 24-27, 1949.....	4	66
5	June 22-30, 1950.....	9	212
6	August 7-15, 1950.....	9	44
7	September 18-25, 1950.....	8	41

(*Catostomus commersonni suckli*) were never abundant but were most numerous during the spring. The longnose sucker (*Catostomus catostomus*) was abundant in the spring and early summer but decreased very markedly in the fall. A few carp (*Cyprinus carpio*) were present in June, July, and August but at no other period of the study. A small number of American burbot (*Lota lota maculosa*) were present in all but one of the sampling periods. Freshwater sculpins (*Cottus bairdi punctulatus*) were abundant in all sections at all sampling periods.

Rainbow trout were planted by the Fish and Game Department in experimental sections four and six as follows: 2,955 fingerlings (2-5 inches) in September 1949, 904 yearlings (average 6.7 inches) in May

1950, approximately 4,000 fingerlings (2-5 inches) in September 1950. Each lot was fin-clipped to make subsequent identification possible. All sections were shocked four times in 1949 and three times in 1950. Each shocking period is designated in consecutive order by a number (Table 1). All fish collected are included in this study except the freshwater sculpins, which were so numerous they could not be collected in the time available. The various species of fish are treated separately with the exception of the longnose and the western white suckers which are combined (suckers). However, the proportion of each species was ascertained during the third sampling period. Of the 34 adult suckers captured, 5 were western white suckers and 29 were longnose suckers.

Brown trout and rainbow trout. — In both years, the number of brown trout and rainbow trout collected increased from June through September but in 1949, when sampling was done in November, a decline in number occurred for both species (Table 2). The apparent increase in number throughout the summer is no doubt due to the greater effectiveness of the electric shocker in stunning fish which had grown somewhat since the previous shocking. The increase in numbers was chiefly in the smaller sized fish. However, the total weight of the brown trout remained more or less constant during the course of each year but was at a much lower level in 1950 than in 1949. The decreased population may be attributed to high mortality during the winter months. The total weight of the wild rainbow trout remained relatively constant in 1949 but increased progressively in 1950. No explanation can be offered for this increase. The number of brown trout in relation to total wild trout population varied from 67.0 percent to 40.2 percent for both years, but the total weight of brown trout in relation to total weight of wild trout varied from 79.4 to 67.4 percent. Wild rainbow trout were second in number among the groups present and make up most of the remainder of the trout population by number and weight (Table 2).

Planted rainbow trout. — The first lot of hatchery rainbow trout was planted on September 8, 1949, and many were captured in the third and fourth sampling periods (Table 2). In 1950, this lot of planted fish constituted less than 2 percent of the total number of trout captured in any of the sampling periods.

The second lot of rainbow trout was planted on May 13, 1950, 41 days before the fifth shocking period. It made up 20.8 percent of the total number of trout in the fifth sampling period, 7.0 percent in the sixth, and 1.7 percent in the seventh.

The third lot of rainbow trout was planted on September 17, 1950, 1 day before the seventh sampling period. The fish in this lot comprised 35.6 percent of the total number of trout in the seventh sampling period but the weight of these trout was only 4.5 percent of the total weight of all trout.

TABLE 2.—The numbers, weights, and percentages of each species of trout captured in each shocking period in Prickley Pear Creek.

Species and shocking period	Number	Percentage of total number of wild trout	Percentage of total number of all trout	Total weight	Percentage of total weight of wild trout	Percentage of total weight of all trout
June 22 to July 13, 1949						
Brown.....	311	67.0	....	125.28	77.0	....
Rainbow.....	140	30.2	....	34.74	21.4	....
Eastern brook.....	10	2.2	....	2.46	1.5	....
Unknown.....	3	0.6	....	0.17	0.1	....
Total.....	464	....	....	162.65	....	....
August 11-17, 1949						
Brown.....	376	65.6	....	108.19	72.3	....
Rainbow.....	175	30.5	....	38.98	26.0	....
Eastern brook.....	21	3.7	....	2.29	1.5	....
Unknown.....	1	0.2	....	0.24	0.2	....
Total.....	573	....	....	149.70	....	....
September 16-23, 1949						
Brown.....	466	57.1	42.5	111.02	73.4	71.9
Rainbow.....	327	40.1	29.8	37.42	24.8	24.2
Eastern brook.....	21	2.6	1.9	1.45	1.6	1.6
Unknown.....	2	0.2	0.2	0.28	0.2	0.2
Total.....	816	....	....	151.17	....	....
Rainbow planted in 1949.....	280	....	25.6	3.28	....	2.1
Grand total.....	1,096	....	....	154.45	....	....
November 24-27, 1949						
Brown.....	324	54.9	48.2	108.96	75.0	74.5
Rainbow.....	252	42.7	37.5	34.04	23.5	23.3
Eastern brook.....	12	2.0	1.8	2.21	1.5	1.5
Unknown.....	2	0.4	0.3	....	....	....
Total.....	590	....	....	145.21	....	....
Rainbow planted in 1949.....	82	....	12.2	1.04	....	0.7
Grand total.....	672	....	....	146.25	....	....

TABLE 2.—Continued

Species and shocking period	Number	Percentage of total number of wild trout	Percentage of total number of all trout	Total weight	Percentage of total weight of wild trout	Percentage of total weight of all trout
June 22-30, 1950						
Brown.....	181	62.2	48.3	77.72	79.4	72.2
Rainbow.....	84	28.9	22.4	14.61	14.9	13.6
Eastern brook.....	21	7.2	5.6	4.77	4.8	4.4
Unknown.....	5	1.7	1.3	0.73	0.8	0.7
Total.....	291	.....	.....	97.83	.....	.....
Rainbow planted in 1949.....	6	.....	1.6	0.26	.....	0.2
in May, 1950.....	78	.....	20.8	9.62	.....	8.9
Grand total.....	375	.....	.....	107.71	.....	.....
August 7-15, 1950						
Brown.....	284	58.6	53.4	70.56	72.0	67.3
Rainbow.....	177	36.5	33.3	25.57	26.1	24.4
Eastern brook.....	21	4.3	3.9	1.79	1.8	1.7
Unknown.....	3	0.6	0.5	0.13	0.1	0.1
Total.....	485	.....	.....	98.05	.....	.....
Rainbow planted in 1949.....	10	.....	1.9	0.93	.....	0.9
in May, 1950.....	37	.....	7.0	5.87	.....	5.6
Grand total.....	532	.....	.....	104.85	.....	.....
September 18-25, 1950						
Brown.....	302	40.2	25.0	68.73	67.4	61.6
Rainbow.....	428	57.0	35.5	30.97	30.4	27.7
Eastern brook.....	16	2.1	1.3	1.26	1.2	1.1
Cutthroat.....	1	0.1	0.1	0.55	0.6	0.5
Unknown.....	4	0.6	0.3	0.42	0.4	0.4
Total.....	751	.....	.....	101.93	.....	.....
Rainbow planted in 1949.....	6	.....	0.5	0.90	.....	0.8
in May, 1950.....	20	.....	1.7	2.81	.....	2.4
in Sept., 1950.....	430	.....	35.6	5.03	.....	4.5
Grand total.....	1,207	.....	.....	111.67	.....	.....

Eastern brook trout.—In 1949, the number of eastern brook trout contributed less than 4 percent of the total trout in any sampling period. Their weight in relation to the total weight of all trout did not exceed 1.6 percent for the same periods.

The total number in 1950 is about the same as for 1949 but the percentage in relation to all trout increased to 7.2 percent. However, this percentage decreased progressively from the fifth to the seventh sampling periods.

Only one cutthroat trout was captured and this was during the seventh shocking period.

Total populations.—The numbers and weight of total trout, mountain whitefish, suckers, carp, and American burbot are given for each shocking period (Table 3). While the number of trout captured fluctuated considerably, the total weight of all trout for the various sampling periods is more or less the same during each year. However, the number and weight was higher in 1949 than in 1950. The number of mountain whitefish was higher during the sampling periods of June in each year than at succeeding shocking periods. There were less mountain whitefish in 1950 than in 1949. The numbers and weight of suckers in 1949 decreased from the first to the fourth sampling periods. The most pronounced decrease in numbers and weights occurred between the first and second shocking periods. While suckers were fewer in 1950 than in 1949, their numbers and weights in relation to other fish show the same general pattern except that the drop occurs between the last two shocking periods. Nine carp were present in the first shocking period and one in the second. Two were present in the sixth sampling period. A few burbot were present in all shocking periods in 1949 and in the fifth and sixth sampling periods of 1950.

Standing populations in Prickley Pear Creek.—The total weight of all fish collected from the six sampling sections during each shocking period was used in calculation of the pounds of fish per acre. The weight of all fish (except freshwater sculpins) in Prickley Pear Creek varied from 81.75 to 241.10 pounds per acre in 1949 and from 58.87 to 148.04 pounds in 1950 (Table 3). This decrease in weight is due primarily to a decline in the number of suckers which disappeared from the study area. In 1949 this decrease occurred chiefly between the first and second shocking periods and in 1950 between the sixth and seventh. At least some suckers moved into the Missouri River as evidenced by two tag returns.

The weight of trout as calculated from all shocking periods decreased from an average of 63.99 pounds per acre in 1949 to 45.13 pounds in 1950. Trout populations remained relatively stable in the sampling periods of each year but showed a significant difference between years. The reason for this difference is unknown but may result from mortality, anglers' catch, or movement into the Missouri River.

The weight of the trout population remained more or less constant during each year though many trout moved out of the study sections. Each time a section was shocked some untagged or "new" trout were captured. Some trout did move outside the sections as shown by random sampling. When trout moved out of a section they were replaced by "new" or unmarked trout of equivalent weight.

TABLE 3.—Numbers, weights, and pounds per acre of fish captured during each shocking period in Prickley Pear Creek.

Group of fish	Number	Percentage of total number	Total weight	Percentage of total weight	Pounds per acre
June 22 to July 13, 1949					
Trout.....	464	57.2	162.65	28.2	67.91
Whitefish.....	75	9.2	40.98	7.1	17.11
Suckers.....	260	32.1	348.86	60.4	145.66
Carp.....	9	1.1	24.26	4.2	10.13
Burbot.....	3	0.4	0.70	0.1	0.29
Total.....	811		577.45		241.10
August 11-17, 1949					
Trout.....	573	82.4	149.70	56.4	62.51
Whitefish.....	21	3.0	21.60	8.1	9.02
Suckers.....	90	13.0	89.59	33.7	37.41
Carp.....	1	0.1	2.24	0.8	0.94
Burbot.....	10	1.5	2.51	1.0	1.05
Total.....	695		265.64		110.93
September 16-23, 1949					
Trout.....	1,096	93.6	154.45	69.9	64.49
Whitefish.....	20	1.7	11.71	5.3	4.89
Suckers.....	52	4.4	53.75	24.3	22.44
Burbot.....	3	0.3	1.18	0.5	0.49
Total.....	1,171		221.09		92.31
November 24-27, 1949					
Trout.....	672	91.1	146.25	74.7	61.06
Whitefish.....	36	4.9	22.18	11.3	9.26
Suckers.....	27	3.7	26.82	13.7	11.20
Burbot.....	2	0.3	0.56	0.3	0.23
Total.....	737		195.81		81.75
June 22-30, 1950					
Trout.....	375	62.0	107.71	30.4	44.97
Whitefish.....	46	7.6	23.90	6.7	9.98
Suckers.....	182	30.1	222.36	62.7	92.84
Burbot.....	2	0.3	0.61	0.2	0.25
Total.....	605		354.58		148.04
August 7-15, 1950					
Trout.....	532	73.2	104.85	31.3	43.78
Whitefish.....	10	1.3	2.74	0.8	1.14
Suckers.....	181	24.9	220.03	65.8	91.87
Carp.....	2	0.3	5.40	1.6	2.25
Burbot.....	2	0.3	1.60	0.5	0.67
Total.....	727		334.62		139.71
September 18-25, 1950					
Trout.....	1,207	89.5	111.67	79.2	46.63
Whitefish.....	8	0.6	1.91	1.4	0.80
Suckers.....	133	9.9	27.40	19.4	11.44
Total.....	1,348		140.98		58.87

Shuck (1945) estimated the average weight of brown trout in Crystal Creek, New York, to be 13.85 pounds per acre based on September samples over a 4-year period. The September samples from Prickley Pear Creek show the average weight of brown trout to be 37.5 pounds per acre. Smith *et al.* (1949) report an average of 251.1 pounds of trout and other fish per acre in the Root River system in Minnesota. The average for Prickley Pear Creek was 131.52 pounds per acre in 1949 and 115.54 pounds in 1950. Shetter and Leonard (1943) give 94.40 pounds per acre as the total weight of brook trout (only trout species present) in Hunt Creek, Michigan. This figure is considerably higher than the 1.4 to 40.0 pounds per acre of trout reported for other Michigan streams (Shetter and Hazzard, 1939). The weight of trout in Prickley Pear Creek for the 2-year period varied from 43.78 pounds per acre to 67.91 pounds. The total weight of fish per acre in six primitive streams in New Hampshire (Hoover, 1938) varied from 29.7 to 158.4 pounds per acre, as compared to Prickley Pear Creek which showed a variation of 58.87 to 241.10 pounds of fish per acre at the different sampling periods.

TABLE 4.—Brown trout tagged and recaptured during 1949 and 1950.

Month tagged	Month recaptured	Number available for recapture	Number recaptured	Number showing no movement	Number moving within section
June 1949	August 1949	278	131	93	38
	September 1949	275	109	60	15
	November 1949	274	83	38	13
	June 1950	267	66	29	11
	August 1950	261	48	18	13
	September 1950	257	38	21	7
August 1949	September 1949	150	88	68	20
	November 1949	150	53	33	11
	June 1950	149	31	8	5
	August 1950	147	23	10	7
	September 1950	145	16	12	2
September 1949	November 1949	172	31	13	17
	June 1950	168	5	0	3
	August 1950	168	9	2	1
	September 1950	168	6	2	1
November 1949	June 1950	97	5	4	1
	August 1950	97	5	0	1
	September 1950	96	4	2	1
June 1950	August 1950	62	16	6	10
	September 1950	60	15	3	4
August 1950	September 1950	77	34	22	12

MOVEMENT OF FISH

Information on the movement of tagged fish was secured by regularly scheduled sampling of the six shocking sections, by shocking selected sections taken at random within the study area, and by creel census.

Movements determined from regularly scheduled shockings. — The movement of tagged fish recovered in the population studies was noted. In the analysis of this information the number of fish caught by anglers is subtracted from the number tagged and the remainder considered to be the number available for recovery (Tables 4 and 5). The number recorded as showing no movement are fish that were recaptured in the same sub-section where tagged or recaptured in the same sub-section, they occupied in the preceding sampling period. The number moving within a section are fish that moved from one sub-section to another in the interim between two successive shocking periods.

Nine hundred forty-four brown trout were tagged including 100 in the last sampling period which were, for the purpose of this study, unavailable for recapture. In subsequent shocking periods 398 or 47 percent of the 844 available fish were recaptured at least once. Many

TABLE 5.—Rainbow trout tagged and recaptured during 1949 and 1950.

Month tagged	Month recaptured	Number available for recapture	Number recaptured	Number showing no movement	Number moving within section
June 1949	August 1949	122	63	43	19
	September 1949	120	54	29	10
	November 1949	120	37	21	8
	June 1950	114	11	4	3
	August 1950	113	14	3	2
	September 1950	113	8	5	2
August 1949	September 1949	103	48	31	17
	November 1949	102	15	6	5
	June 1950	95	6	3	0
	August 1950	94	6	0	0
	September 1950	94	2	0	0
September 1949	November 1949	65	15	9	6
	June 1950	62	4	2	1
	August 1950	58	3	1	1
	September 1950	58	3	1	2
November 1949	June 1950	69	6	2	4
	August 1950	66	4	2	0
	September 1950	65	3	2	0
June 1950	August 1950	47	16	10	6
	September 1950	46	17	7	5
August 1950	September 1950	110	55	30	25

brown trout were recovered more than once and 10 were recaptured six times (Table 6). The tagged brown trout present in each shocking period showed a marked decrease in recaptures during the next subsequent sampling period. The rate of recovery thereafter exhibited a more or less gradual decline for the remaining shocking periods. The disturbance of the fish population at the time of sampling and tagging may have caused the fish to move out of the section and mortality resulting from handling and tagging may have reduced the total numbers. Evidence of movement out of a section was observed

when the areas immediately above and below Section 5 were sampled 22 days after the second shocking period. Five tagged brown trout were found within 200 feet of the lower boundary of the section and three were found within 500 feet of the upper boundary of the section. This recovery accounted for only 5 percent of the brown trout that were missing from Section 5 in the second shocking period. However, a more extensive movement out of a section was shown by a brown trout which moved downstream 2.3 miles between September 22 and November 26, 1949. The number of brown trout that were found in the same sub-section from one shocking period to the next was remarkably high (Table 4). The movement from one sub-section to another within the section shows no discernible pattern. Of 638 rainbow trout tagged, 528 were available for recovery (Table 6). During subsequent sampling periods 242 or 46 percent were recaptured at least

TABLE 6.—Number of fish marked and times recaptured.

Species	Number tagged	Number of fish and times recaptured					
		1	2	3	4	5	6
Brown trout.....	844	181	114	44	29	20	10
Rainbow trout.....	528	153	53	21	6	8	1
Eastern brook trout.....	87	10	1	3	1		
Whitefish.....	155	7					
Suckers.....	767	26	8		1		
Carp.....	11						
American burbot.....	3						

once. About one-third were recovered more than once and one was recovered six times. The percentages of rainbow trout recovered in the different shocking periods were about the same as that exhibited by the brown trout. The percentage of rainbow trout recovered after one winter at large was less than brown trout. Movements of rainbow trout between sections were as follows:

- 6.9 miles upstream from July 12 to August 13, 1949,
- 4.6 miles downstream from August 12 to November 27, 1949,
- 4.6 miles upstream from September 18, 1949 to June 30, 1950,
- 6.9 miles downstream from September 20, 1949 to June 22, 1950,
- 2.3 miles downstream from November 24, 1949 to August 11, 1950.

Although the sample is small the data secured on movement from one regular section to another demonstrate that rainbow trout moved more than brown trout.

Only 87 eastern brook trout were tagged and of these 76 were available for recapture (Table 6). All of the 15 specimens recaptured were taken in the sections where they were tagged.

Only 7 of the 155 whitefish marked and available for recovery were recaptured and each was found in the sections where they were marked.

A total of 767 suckers were marked during this study. Fifteen were tagged in the last sampling period. Of the 752 suckers available for

recovery 35 were recaptured at least once and one of these was recaptured four times. Only two were recaptured in a section other than that in which they were tagged. These had moved downstream as follows: 6.9 miles between June 30 and August 15, 1949, 6.9 miles between June 23 and 29, 1950. This last movement approaches a rate of 1 mile per day. None of the tagged burbot or carp were recovered in subsequent shocking of the regular sections.

Movements determined by sampling random sections. — In 1950, sampling areas chosen at random, as described by Snedecor (1946), were shocked in order to determine the movement of tagged fish outside the regular sections. Eleven random sections each 300 feet in length were sampled by regular shocking methods between July 5 and 13, 1950. One random section coincided with part of the regular Section 6 and one bordered the lower boundary of Section 5. No fish were marked during this operation.

Of the 24 tagged brown trout recovered only 6 were found outside a regular section. All had moved downstream. Four of these were captured in a random section that bordered Section 5. One brown trout was captured in another random section 500 feet from Section 5 and one was captured in a random section 1,300 feet from the same section. The average distance these six brown trout moved away from place of tagging and release was 700 feet, with a maximum distance of 1,900 feet. All were tagged in 1949.

Of the five tagged rainbow trout recovered, three were found outside of a regular section. One was recovered in a random section 1,300 feet from Section 5, having moved downstream 1,500 feet from place of tagging and release. Two were recovered in the random section that bordered Section 5. The average distance moved was 780 feet downstream. These trout were tagged in 1949. Only two eastern brook trout were recovered and these were in the random section in regular Section 6. One mountain whitefish was recovered in a random section downstream from Section 5. It had moved 1,500 feet.

Fourteen suckers were recaptured in the random sections. One was recovered in the random section in Section 6. The remainder were scattered in nearly all of the other random sections. Six of these were found upstream on an average of 1.3 miles from the place of tagging. The maximum distance moved was 2.3 miles. Seven suckers had moved downstream an average of 2.3 miles. The maximum distance was 9.1 miles. One sucker moved downstream 5.0 miles between June 30 and July 6, 1950. Three of the recovered suckers were tagged in 1949 and the remainder in 1950. No tagged carp or burbot were found in the sampling of the random sections.

Movement determined by creel census.—A partial creel census was made in the summer of 1949 and an intensive creel census during the summer of 1950. This project was given publicity in the local newspapers and many signs were posted along the creek instructing anglers

to report all information on fish caught, especially marked fish. Although much information was collected in this manner, it is known that the returns were not complete.

A total of 36 marked brown trout were caught by anglers, and reliable information on the location of catch was available on 27. Thirteen were caught in the sections where tagged, one was captured 0.1 miles upstream from point of tagging, and the other 13 moved downstream for an average of 5.2 miles (minimum 0.1, maximum 27). Of the downstream migrants, five were captured in the Missouri River. One of these had moved approximately 27 miles between July 8, 1949, and May 2, 1950.

Accurate location information was secured on 32 of the 44 rainbow trout caught by anglers. Sixteen were caught in the section where tagged. Five moved upstream between June 30, 1949 and August 27, 1950, for an average distance of 4.4 miles (minimum 0.1, maximum 11.5). Nine moved downstream between June 23, 1949, and December, 1950, for an average of 0.3 miles (minimum 0.1, maximum 10.2).

Seven marked eastern brook trout were caught by anglers. Only one was caught outside a section and it moved 2.3 miles upstream between June 22 and July 4, 1950.

Ten of the 14 suckers caught by anglers had accurate location data. Six of these were tagged in 1949 and the remainder in 1950. Two were caught where they had been tagged while two moved upstream for an average of 1.4 miles. The maximum distance moved upstream was 2.4 miles between September 23, 1949 and May 21, 1950. Of the six suckers that moved downstream two were caught in the Missouri River. The average distance moved was 2.2 miles downstream (minimum 0.4 mile) with the greatest distance being 5.6 miles between June 23 and August 9, 1950. No returns were obtained on mountain whitefish, carp, and burbot by creel census.

The movement of trout and suckers that were captured outside the regular sections in which they had been tagged was generally downstream. Of the 29 brown trout captured outside of a section where they had been tagged, 25 had moved downstream and 4 moved upstream. Of the 22 rainbow trout that were recovered outside a section where they had been tagged, 15 had moved downstream and 7 moved upstream. Twenty-three suckers were captured outside a section where they had been tagged and of these, 15 had moved downstream and 8 upstream. The drastic reduction of suckers in the summer suggests a mass exodus of this species out of the study area. There is indication that some suckers move rapidly downstream as demonstrated by one which moved 6.9 miles in 7 days.

Creel census was shown to be the most effective method for obtaining returns on movement of fish, since sampling of random sections was too time consuming and costly and sampling of the regular sections did not give much information on the movement of fish.

ACKNOWLEDGMENTS

The writer is indebted to several individuals and agencies who assisted in this study. Dr. C. J. D. Brown gave overall direction to this investigation and helped in the preparation of the manuscript. Mr. Charles K. Phenicie suggested the problem and rendered active assistance in its direction. The following field biologists assisted in the shocking operations: W. Alvord, J. E. Bailey, W. D. Clothier, V. E. Craig, J. W. Kathrein, and T. J. Ready.

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DOWNSTREAM MOVEMENT OF RECENTLY TRANSFORMED SEA LAMPREYS, *PETROMYZON MARINUS*, IN THE CARP LAKE RIVER, MICHIGAN¹

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ABSTRACT

In order to obtain more precise information concerning the downstream movement of recently transformed sea lampreys, a trapping device was operated in the Carp Lake River, Emmet County, Michigan, from October, 1948, to July, 1951.

The period of downstream migration typically extends from the latter part of October to the middle of April. It varies, however, from year to year with climatic conditions. A few migrants usually appear every day during this period but a sudden increase in water level is characteristically accompanied by a surge in downstream movement of newly transformed sea lampreys. This phenomenon is realized principally during the spring floods and often concurrently with autumn rains and mid-winter thaws.

A total of 7,969 downstream migrants were taken in the 1948-49 season; 16,235 in 1949-50, and 15,103 in 1950-51. Measurements of representative samples from the total catch of sea lamprey migrants of the 1948-49 and 1949-50 seasons revealed a range in length of 95 to 190 millimeters and an average length of 145 millimeters (3.7 to 7.5 inches; mean —5.7 inches).

INTRODUCTION

The invasion of the upper Great Lakes by the parasitic sea lamprey, its explosive increase in these waters, and the destructive effects of its attacks upon commercial and game fishes have been adequately reviewed in many recent reports. A comprehensive study of the biology of the lamprey is basic to the current program aimed at reducing the numbers of this destructive predator. These investigations were designed to gain information on the life history, habits, and physiology of the parasite that might contribute toward the development of more effective control methods. The downstream migration of each succeeding year class of newly transformed individuals is considered to be one of the most vulnerable stages at which the species may be attacked. Destruction of sea lampreys at this time has the advantage of eliminating the entire annual production of young from a watershed before they enter upon the parasitic phase of their existence.

At the inception of these studies, there was some uncertainty about the precise time downstream movement of recently transformed, adult sea lampreys occurred. Furthermore, ecological factors influencing

¹Contribution from the Michigan Institute for Fisheries Research.

these movements were unknown. Occasional field observations and studies of larval populations suggested that this movement took place during the winter and/or spring months. In order to obtain more information on this phase of the life cycle, a trapping device was operated in the Carp Lake River, Emmet County, Michigan, from October, 1948, to July, 1951. A preliminary analysis of the runs occurring in the 1948-1949 season in this stream and in the Ocqueoc River, Presque Isle County, Michigan, has been presented by Applegate (1950). The present report concerns the downstream movements in the Carp Lake River during three consecutive seasons.

Support for this study was provided initially by the Michigan Institute for Fisheries Research which constructed the original trapping device and operated the structure until January, 1950. Thereafter, the study was carried on as a cooperative project between that organization and the U. S. Fish and Wildlife Service.

THE CARP LAKE RIVER DAM AND INCLINED-SCREEN TRAP

The Carp Lake River which drains into the Straits of Mackinac on its southwest shore arises about 9 miles from the straits in Carp Lake. This lake has an area of 1,823 acres and one small tributary, Mud Creek. A moderately large spawning run of sea lampreys was observed in this river in 1947 and extensive spawning activity was noted. This fact and the presence of extensive areas of suitable larval habitat suggested that the potential stock of downstream migrants might be large enough to justify the construction of a trapping device.

The trapping device selected for this experiment required the construction of a dam. The lowest suitable site was about 1,500 feet above the mouth of the river where the stream was 32 feet wide. Little spawning occurred below this site in 1947. During the period January-May, 1948, a wooden dam 60 feet wide and 5½ feet high, was constructed on this location. The wall of the dam was constructed of a double row of 2- by 6-inch, tongue-and-groove planks supported by round timbers. A spillway, 15½ feet wide, 2 feet deep, and 9½ feet long carried the water passing over the dam. Bracing timbers and large rocks piled against the downstream side gave the dam wall additional support.

The trapping device was composed of a sloping screen and a trap box. The former consisted of a 1½-inch angle-iron frame, 15½ feet long and 30 inches wide, over which two layers of wire screen were stretched taut with a hydraulic jack. The lower layer was of ½-inch mesh, hardware cloth and the surface layer was of 18-mesh/inch copper screen. This screen unit was installed 6 inches below the lip of the spillway and inclined downward and downstream at a 12° angle. An additional unit, 12 inches wide, was added later to carry larger water volumes. Below the lip of the screen and along its full width,

a trap box was built. This box measured 30 inches wide by 24 inches deep and was lined with 14-mesh/inch screen. The level of the floor of the box was above normal water levels in the stream.

All water passing over the spillway fell almost vertically through the screen. Algae, fine detritus, and silt were forced through the screen by the impact of the water. The slope of the screen and the action of the water caused all larger items including lampreys coming down on the current to be forced off the screen into the trap box. The screen itself was entirely self-cleaning and required little attention. Fish and lampreys accelerated their movement off the screen by wriggling or flopping movements. During the winter months, ice did not form upon the inclined screen in such a manner as to hamper its function. The entire device operated satisfactorily during long periods of cold weather



FIGURE 1.—Dam and inclined-screen sea lamprey trap in the Carp Lake River, Emmet County, Michigan (Final, improved structure).

with only one modification. The box was replaced with a simple wooden baffle plate (15 inches high) placed across the foot of the inclined screen. The thin coat of ice that formed on this baffle could be removed. Lampreys, fish, and detritus collected in a windrow at the base of the plate. In the summers of 1949 and 1950 the entire structure was converted to a permanent device by the addition of steel sheet-piling in the dam wall, widening of the spillways, and the use of concrete in all spillways and screen supports (Figure 1).²

²Development of the principle of operation of this trapping device is credited to Mr. Philip Wolf of Malmö, Sweden.

The dam and trap was inspected once to three times each day by an attendant. Records were kept of all lampreys, fish, reptiles, and mammals taken. All lampreys were preserved in 10-percent formalin for later examination. Air and water temperatures (taken with maximum-minimum thermometers), water-level-gauge readings, and observations upon the weather and general conditions prevailing in the watershed were taken daily.

A total of 39,307 fully transformed sea lampreys, 67 partly transformed sea lampreys, 517 adult lampreys of other species, 21,663 larval lampreys, and 13,319 other fish were captured during the entire period of operation. Of the fully transformed sea lampreys, 7,969 were taken during the 1948-1949 season, 16,235 in the 1949-1950 season, and 15,103 in the 1950-1951 season.

THE DOWNSTREAM MOVEMENT AND FACTORS AFFECTING MIGRATION

The downstream movement of recently transformed sea lampreys usually begins during the last week in October or the first week in November, extends through the winter and early spring months, and ends during the early part of April. Only a few scattered individuals migrate before or after this season. The migration is usually greatest during late March and early April with a lesser peak of activity in November. During the intervening winter months, a few come downstream nearly every day. Sudden minor spurts of activity may also occur during this period.

Most increases in movement appear to be associated with rising or fluctuating water levels. Late fall rains which increase the flow bring down the initial surge of newly transformed individuals. Flood conditions resulting from mid-winter thaws and rains are often accompanied by sudden increases in downstream movement. The greatest downstream migration occurs on the rise and crest of the floods resulting from the general spring break-up in late March or early April. For this reason, the calendar dates of the migration vary from year to year and from one watershed to another.

Although nearly all of the downstream migration occurred after the mean daily water temperature had fallen below 41° F., there was no evident relationship between changes in water temperature and the amount of migratory activity.

Of the following descriptions of the migrations of newly transformed sea lampreys in the seasons of 1948-49, 1949-50, and 1950-51, all are illustrated by diagram but to avoid the presentation of an excessive amount of tabular material, daily records of data are given for the 1949-50 season only.

In the Carp Lake River in the 1948-1949 season, a single fully transformed sea lamprey came downstream into the trap on October 7, 1948; two additional individuals were taken on October 21 and October 23

(Fig. 2). Sustained downstream movement began on November 2, reached a sharp peak on November 21, and then subsided with equal rapidity. Some movement continued until December 9. The early portion of this period was characterized by rising water levels resulting from light rains and wet snow. Heavy rains from November 17 to 19 increased the volume of flow. The flood crested on the night of November 20-21 and on that night a sudden surge of migrants appeared (3,467 individuals between nightfall and daylight). Subsiding water levels were

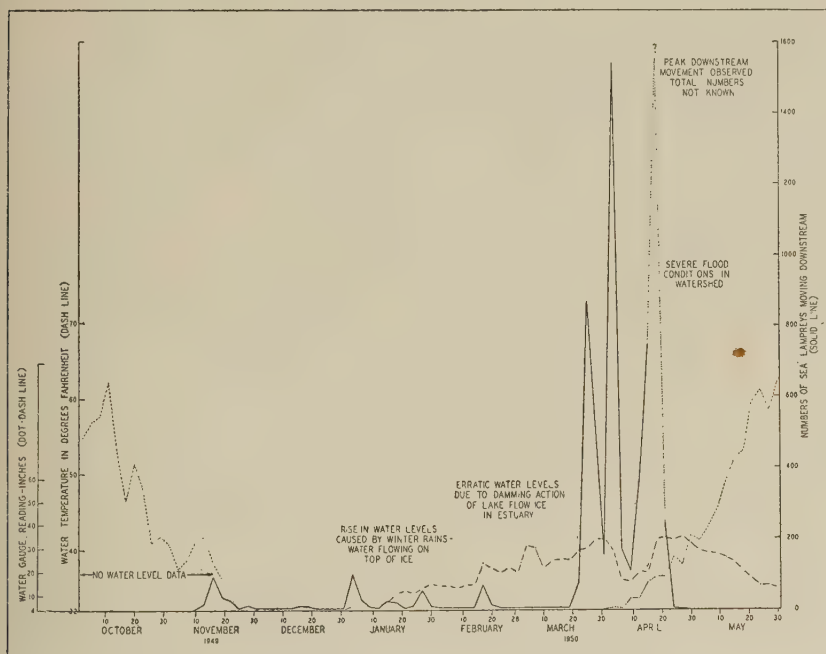


FIGURE 2.—Numbers of recently transformed sea lampreys migrating downstream in the Carp Lake River and fluctuations of water level and water temperature during the 1948-1949 season. All points based on 3-day means. Scales were so computed that the sums of the vertical distances above the base are the same for all three variables for the days with full records.

accompanied by a decline in migration until December 9. From this date until March 22, 1949, downstream movement was of a minor nature. Between January 17 and 24, cold rains increased the flow in the river. Most of this water was passed downstream on top of the ice which had covered nearly all of the river since mid-December. A similar condition prevailed between February 23 and 27 as a result of snow, sleet, rains, and a light thaw. Both of these brief increases in volume of flow were accompanied by spurts of downstream migration.

Warm winds in the Carp Lake region from March 20 to 25 were followed by severe flood conditions as snow and ice melted rapidly. Water levels rose abruptly on March 22. The major downstream movement of lampreys began. On March 26, the water overtopped the dam, undercut one wing, and destroyed the trap box. The structure was not restored to full operating efficiency until April 18. During the period March 26-April 3, a great number of downstream migrants was observed passing over the dam during the daylight hours. Many of these accumulated under the lip of the spillway and behind the stream of falling water. This space, triangular in cross section, had a base on the screen about 5 inches wide. On March 26, 24 hours after the flood over-topped the dam, access was gained to a 30-inch length of this air space. We removed 614 sea lampreys from this limited area. It was also determined visually that an equivalent concentration was trapped beneath the entire lip of the spillway. It is estimated, therefore, that between 3,000 and 4,000 migrants had accumulated in this small air pocket in the first 24 hours after the trap had been rendered inoperative. This number represents only a small fraction of the total number that passed downstream.

A few sea lampreys were observed migrating during daylight hours between April 3 and 10; thereafter, none were seen. Water levels declined during this period and on April 18, when the trap was again operative, they had receded to about mean spring levels. Between April 19 and 23, seven individuals came downstream. From the latter date until June 30, when these records terminate, no others appeared.

In the 1949-50 season, migratory activity began when two fully transformed individuals came downstream on November 1, 1949 (Fig. 3, Table 1). Scattered migrants moved downstream until November 14 when rains and melting snow raised the river level. In the succeeding 3 days this season's first surge of migrants appeared in the trap. This surge gradually subsided as water levels receded during the balance of the month. Freezing temperatures stabilized water levels until January 3, 1950, when winter rains increased the volume of flow. Concurrently with this minor mid-winter flood there was a low peak of downstream movement. Thereafter a sustained and severe drop in air temperature caused the river to freeze throughout its entire course making it necessary for any excess water to flow on top of the ice. Intermittent rain, sleet, and brief thaws from January 14 to 29 aided in maintaining high and fluctuating water levels. This period produced two minor peaks in lamprey movement corresponding to the two peak flood levels. A similar situation prevailed between February 13 and 23, as a result of snow storms and subsequent thaws.

An upward trend in air temperature beginning March 20 precipitated the spring break-up and major flood conditions prevailed. On March 22, the principal downstream movement of the season began. This migration continued in a sustained but fluctuating manner until April 18. From the latter date until April 22 the trapping screens were removed from the dam to permit the passage of an unprecedented flood. A considerable

number of migrants passed downstream during the early part of this 3-day period. After the resumption of trapping operations on April 22 only scattered migrants were taken until May 31; thereafter no others appeared.

The downstream movement of newly transformed sea lampreys in the 1950-51 season began September 22, 1950 (Fig. 4). Only scattered migrants were trapped until November 1, when a slight rise in water

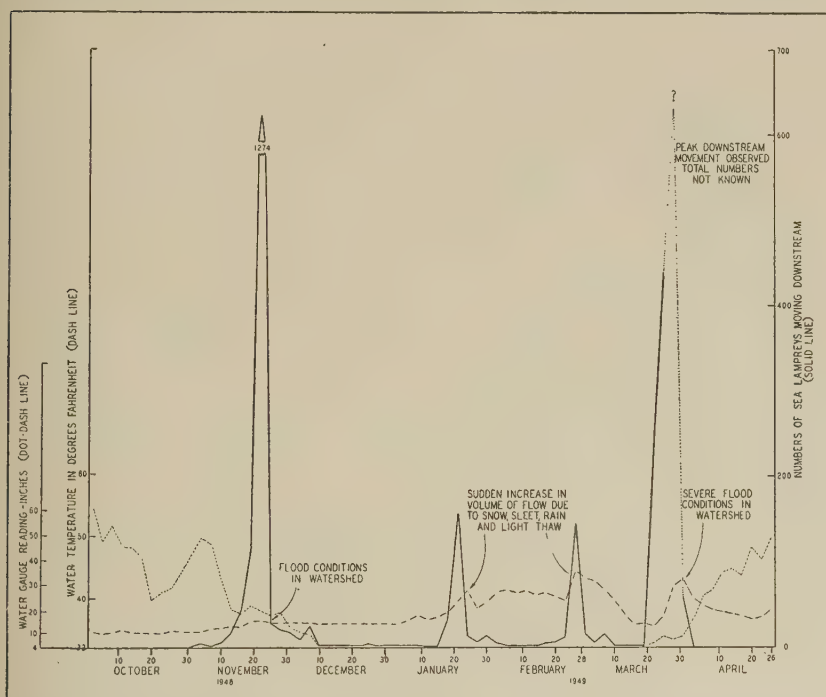


FIGURE 3.—Numbers of recently transformed sea lampreys migrating downstream in the Carp Lake River and fluctuations of water level and water temperature during the 1949-1950 season. All points based on 3-day means. Scales were so computed that the sums of the vertical distances above the base are the same for all three variables for the days with full records.

level apparently stimulated a more or less sustained movement downstream. Rain and melting snow during this period greatly increased the volume of flow until about December 15. During the entire period the numbers of migrants fluctuated closely in accordance with changes in volume of water flow.

The next noticeable increase in migration was on February 26, 1951. On and after this date water levels rose several times with periods of

thawing weather. On March 28 the major break-up began and severe flood conditions prevailed during the following month. Apparently the bulk of the migrants passed downstream during the first 12 or 13 days after the break-up began. Maximum flood conditions actually were not reached until April 13 when it became necessary to discontinue operation of the trap for several days. According to the weir attendant, only a few lampreys were observed coming downstream during this period. From April 18, when trapping operations were resumed, until the last day of May only a few stragglers were taken in the trap; thereafter none was taken.

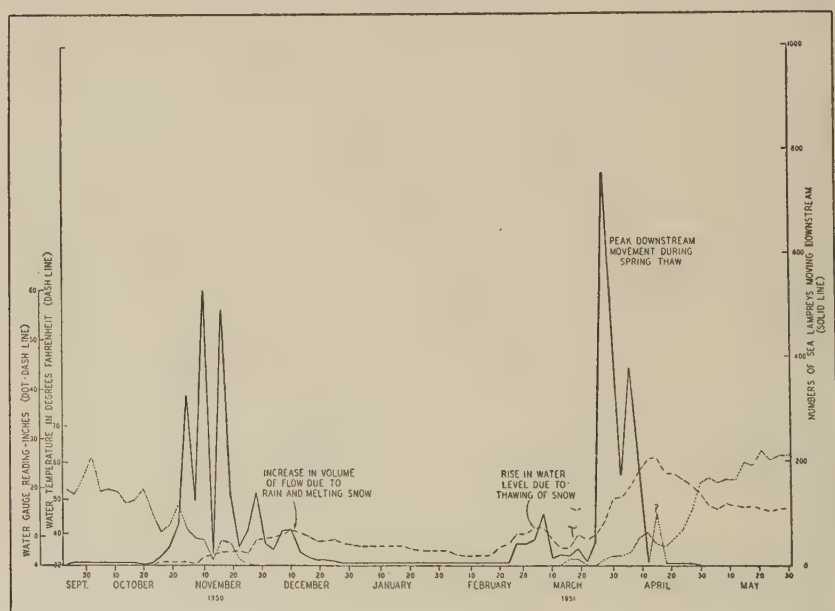


FIGURE 4.—Numbers of recently transformed sea lampreys migrating downstream in the Carp Lake River and fluctuations of water level and water temperature during the 1950-1951 season. All points based on 3-day means. Scales were so computed that the sums of the vertical distances above the base are the same for all three variables for the days with full records.

According to observations made during the three seasons' migrations in the Carp Lake River, the initial surge of downstream movement in November occurred during declining water temperatures when the daily mean was 41°F. or lower. The single exception was noted in 1950 when 261 lampreys came downstream on November 3 although the mean water temperature was 44°F. Mid-winter increases in downstream movement occurred at water temperatures which were stabilized very near 32°F. The greatest movement, in late March and early April, took place during

periods of rising water temperatures and almost entirely at daily means below 41°F. Since there appears to be no relationship between fluctuations in water temperature and the amount of migratory activity, these temperatures are merely coincident with the season when the lampreys have attained full transformation and are ready to move downstream. All evidence accumulated thus far indicates that the stimulus for this movement is provided primarily by sudden increases in the stream flow. At times only a small rise in water level will cause an appreciable number of individuals to start their journey downstream.

LENGTH AND WEIGHT OF MIGRANTS

All recently transformed sea lampreys taken on every other day in the 1948-49 and 1949-50 seasons in the Carp Lake River were measured for total length to the nearest millimeter. A total of 2,482 individuals of the 1948-49 run and 2,492 specimens of the 1949-50 run were examined. Fully transformed downstream migrants taken from this stream in the 1948-49 season ranged from 95 to 189 millimeters in total length and averaged 143.6 millimeters (S.D., ± 10.8 millimeters) (3.7 to 7.4 inches; mean — 5.7 inches); those of the 1949-50 season ranged from 103 to 191 millimeters and averaged 145.2 millimeters (S.D. ± 11.6 millimeters) (4.1 to 7.5 inches; mean — 5.7 inches). The length frequency distributions of the annual samples were unimodal, and the frequency polygons for both are quite symmetrical (Fig. 5). The polygons exhibit neither the bimodality nor the irregular "flattening" that might be expected if sexual difference in length existed at this phase of the life cycle.

A progressive increase in the size of migrants evidently occurs during the period of downstream movement. Comparisons of length-frequency distributions for each month and of the mean lengths of the daily samples (Table 1) indicate that the smallest individuals usually moved downstream in the fall. A general increase occurred in the average total length during the winter months and was greatest during late winter and early spring when migratory activity was at its peak.

One sample consisting of 216 migrants was taken on November 20, 1948, and each individual was weighed on a dietary scale to the nearest 0.1 gram. The weights of the individuals varied from 2.3 grams to 8.4 grams and averaged 4.1 grams. Their total lengths ranged from 121 to 172 millimeters and averaged 143.0 millimeters.

HABITS AND BEHAVIOR

One of the most striking characteristics of the migration of newly transformed sea lampreys is the suddenness with which large numbers of individuals leave the mudbanks and move downstream. Under the impetus of rising waters, a virtual "emergence" takes place and large numbers of the small lampreys travel downstream on the rise and crest of the floodwaters. This surge frequently ends as suddenly as it began.

TABLE 1.—Numbers and minimum, average, and maximum total lengths of newly transformed sea lampreys migrating downstream in the Carp Lake River during the winter of 1949-50, with weather, water-temperature and water-level data for the period [Readings and observations made at 8:00 a.m. each day].

Date 1949-1950	Mean water temperature (Deg. F.)	Water level (inches)	Weather	Number taken	Sea lampreys Total length (millimeters)		
					Minimum	Average	Maximum
Nov. 1	40.0	.....	Clear	2	142	145.5	149
2	40.0	.....	Overcast	1	.....	.....	.....
3	38.5	.....	Overcast	0	.....	.....	.....
4	37.5	.....	Snow	1	.....	(129.0)	.....
5	36.5	.....	Clear	0	.....	.....	.....
6	37.0	.....	Overcast	2	135	146.0	157
7	38.0	.....	Clear	0	.....	.....	.....
8	41.0	.....	Clear	0	.....	.....	.....
9	42.5	.....	Clear	0	.....	.....	.....
10	39.0	.....	Clear	3	130	146.7	170
11	42.0	.....	Overcast	1	.....	(136.0)	.....
12	43.0	.....	Overcast	1	.....	(125.0)	.....
13	42.0	.....	Rain	7	128	141.6	150
14	40.0	.....	Snow	50	.....	.....	.....
15	39.0	.....	Snow	96	120	147.0	175
16	38.0	.....	Overcast	133	.....	.....	.....
17	38.0	4.0	Overcast	45	126	146.5	165
18	37.0	4.0	Overcast	32	.....	.....	.....
19	36.0	4.0	Overcast	43	116	146.2	188
20	35.0	4.2	Overcast	30	.....	.....	.....
21	35.0	4.2	Overcast	40	.....	.....	.....
22	34.5	4.2	Overcast	12	.....	.....	.....
23	32.5	4.5	Overcast	24	116	132.4	152
24	32.0	4.5	Overcast	8	.....	.....	.....
25	32.0	4.5	Overcast	7	128	142.3	165
26	32.0	4.5	Overcast	8	.....	.....	.....
27	32.0	4.2	Snow	12	125	141.6	154
28	32.0	4.0	Overcast	13	.....	.....	.....
29	32.0	4.0	Rain	18	124	142.4	160
30	32.5	4.2	Overcast	6	.....	.....	.....
Dec. 1	32.0	4.2	Overcast	3	121	140.0	157
2	32.0	4.0	Snow	2	.....	.....	.....
3	32.0	4.0	Overcast	1	.....	(149.0)	.....
4	32.0	4.0	Rain	2	.....	.....	.....
5	32.0	4.0	Snow	2	147	147.5	148
6	32.0	4.0	Overcast	0	.....	.....	.....
7	32.0	4.0	Clear	5	132	140.4	153
8	32.0	4.0	Overcast	3	.....	.....	.....
9	32.0	4.0	Overcast	6	129	140.5	151
10	32.0	4.0	Overcast	3	.....	.....	.....
11	32.0	5.0	Rain	6	126	146.0	159
12	32.0	5.0	Overcast	0	.....	.....	.....
13	32.0	5.0	Overcast	6	130	142.0	158
14	32.0	5.0	Overcast	16	.....	.....	.....
15	32.0	5.0	Overcast	15	126	143.2	161
16	32.0	5.0	Overcast	7	.....	.....	.....
17	32.0	5.0	Overcast	14	127	141.3	160
18	32.0	5.0	Rain	14	.....	.....	.....
19	32.0	4.5	Overcast	10	132	144.6	158
20	32.0	4.5	Overcast	6	.....	.....	.....
21	32.0	4.5	Overcast	3	134	142.0	156
22	32.0	4.5	Snow	4	.....	.....	.....
23	32.0	4.0	Overcast	3	132	145.7	155
24	32.0	4.0	Overcast	2	.....	.....	.....
25	32.0	4.5	Overcast	5	126	143.6	162
26	32.0	4.5	Overcast	5	.....	.....	.....
27	32.0	4.0	Snow	1	.....	(129.0)	.....
28	32.0	4.0	Overcast	10	.....	.....	.....
29	32.0	4.0	Clear	3	139	159.3	171
30	32.0	4.0	Clear	2	.....	.....	.....
31	32.0	4.5	Rain	0	.....	.....	.....
Jan. 1	32.0	4.5	Rain	1	.....	(136.0)	.....
2	32.0	4.5	Rain	2	.....	.....	.....
3	32.0	7.0	Rain	118	124	144.1	179
4	32.0	6.0	Overcast	228	.....	.....	.....
5	32.0	5.5	Snow	61	123	149.2	175

TABLE 1.—Continued

Date 1949-1950	Mean water temperature (Deg. F.)	Water level (inches)	Weather	Number taken	Sea lampreys Total length (millimeters)		
					Minimum	Average	Maximum
Jan. 6	32.0	5.5	Overcast	26			
7	32.0	5.5	Clear	5	149	154.0	159
8	32.0	5.5	Clear	12			
9	32.0	7.0	Clear	10	140	151.6	171
10	32.0	6.0	Rain	4			
11	32.0	6.0	Overcast	3	141	143.7	148
12	32.0	6.0	Overcast	2			
13	32.0	6.0	Rain	6	140	152.8	163
14	32.0	7.0	Rain	4			
15	32.0	8.0	Snow; rain	43	129	150.0	173
16	32.0	7.0	Snow	26			
17	32.0	11.0	Clear	45	132	151.3	183
18	32.0	11.0	Snow	16			
19	32.0	11.0	Snow	4	139	148.3	159
20	32.0	12.0	Snow	2			
21	32.0	12.0	Snow	4	135	151.8	161
22	32.0	12.0	Overcast	10			
23	32.0	12.0	Snow	15	128	149.4	182
24	32.0	10.0	Snow	5			
25	32.0	12.0	Overcast	18	127	144.7	185
26	32.0	12.0	Overcast	45			
27	32.0	12.5	Clear	65	126	144.0	179
28	32.0	15.0	Overcast	49			
29	32.0	14.5	Snow; rain	12	121	138.3	156
30	32.0	14.5	Clear	10			
31	32.0	16.0	Snow	7	137	149.9	165
Feb. 1	32.0	14.0	Clear	5			
2	32.0	14.0	Clear	6	127	146.8	168
3	32.0	15.0	Clear	3			
4	32.0	15.0	Clear	2	133	134.5	136
5	32.0	14.0	Overcast	2			
6	32.0	14.0	Overcast	5	127	138.0	159
7	32.0	13.5	Clear	1			
8	32.0	13.0	Clear	3	129	148.0	160
9	32.0	13.0	Overcast	3			
10	32.0	15.0	Overcast	1			
11	32.0	15.0	Overcast	4			
12	32.0	14.0	Snow	7			
13	32.0	14.0	Overcast	11	133	146.8	163
14	32.0	16.0	Snow	7			
15	32.0	14.0	Snow	0			
16	32.0	24.0	Overcast	75	126	147.9	172
17	32.0	24.0	Overcast	110			
18	32.0	23.0	Overcast	20	119	145.8	171
19	32.0	22.0	Snow	10			
20	32.0	20.0	Clear	16	131	152.1	173
21	32.0	23.0	Snow	14			
22	32.0	22.0	Snow	5	140	153.6	184
23	32.0	21.0	Overcast	6			
24	32.0	17.0	Snow	4	138	150.5	165
25	32.0	21.0	Snow	2			
26	32.0	22.0	Snow	0			
27	32.0	23.0	Clear	2			
28	32.0	20.0	Snow	1		(137.0)	
Mar. 1	32.0	20.0	Snow	3	128	137.0	148
2	32.0	20.0	Snow	4			
3	32.0	32.0	Clear	6	120	134.3	163
4	32.0	32.0	Overcast	7			
5	32.0	30.0	Clear	1		(142.0)	
6	32.0	29.0	Clear	0			
7	32.0	32.0	Overcast	2		(153.0)	
8	32.0	30.0	Snow; rain	3			
9	32.0	18.5	Clear	2	139	145.5	152
10	32.0	22.0	Clear	4			
11	32.0	24.0	Snow	1		(158.0)	
12	32.0	25.0	Clear	1			

TABLE 1.—Continued

Date 1949-1950	Mean water temperature (Deg. F.)	Water level (inches)	Weather	Number taken	Sea lampreys Total length (millimeters)		
					Minimum	Average	Maximum
Mar. 13	32.0	25.0	Clear	4	114	133.8	150
14	32.0	25.0	Overcast	4			
15	32.0	25.0	Clear	1		(128.0)	
16	32.0	25.0	Clear	1			
17	32.0	26.0	Snow	5	133	144.0	164
18	32.0	18.0	Clear	3			
19	32.0	28.0	Clear	1		(142.0)	
20	32.0	30.0	Overcast	8			
21	32.0	28.0	Overcast	2			
22	32.0	28.0	Overcast	50			
23	32.0	31.0	Fog	181	126	148.3	175
24	32.0	30.0	Clear	138			
25	32.0	28.0	Clear	100	126	150.3	190
26	32.0	33.0	Overcast	2,365			
27	32.0	32.0	Rain	345	120	148.3	187
28	32.0	36.0	Rain; snow	750			
29	32.0	34.0	Clear	533	122	147.2	178
30	32.0	34.0	Clear	169			
31	32.0	34.0	Overcast	76	121	140.6	168
Apr. 1	32.0	34.0	Snow	214			
2	32.0	36.0	Overcast	299	118	141.1	182
3	32.0	34.0	Overcast	614			
4	33.0	18.0	Snow	3,711	103	138.8	163
5	32.5	17.0	Snow	284			
6	32.0	17.0	Clear	41	117	143.5	172
7	32.0	16.0	Overcast	188			
8	32.5	16.0	Clear	164			
9	33.5	16.0	Overcast	148			
10	34.5	16.0	Rain	9	130	143.9	161
11	34.0	21.0	Rain	19			
12	33.5	20.0	Rain	855	115	140.6	177
13	33.0	19.5	Overcast	219			
14	33.0	19.0	Snow	51	120	144.8	172
15	36.0	19.0	Clear	770			
16	37.0	22.0	Clear	1,426	105	140.2	165
17	37.0	29.0	Clear	794			
18	36.0	35.0	Clear				
19	36.0	38.0	Overcast				
20	35.0	37.0	Rain; snow				
21	36.0	34.0	Overcast				
22	38.0	33.0	Overcast	4			
23	37.0	33.0	Overcast	2			
24	40.0	34.0	Clear	3			
25	40.0	34.0	Rain	5		(147.0)	
26	38.0	36.0	Overcast	6			
27	38.0	36.0	Overcast	0			
28	38.0	34.0	Overcast	0			
29	39.0	34.0	Clear	2			
30	44.0	32.0	Overcast	1			
May 1	42.0	31.0	Overcast	0			
2	40.0	30.0	Clear	0			
3	42.0	29.0	Overcast	2			
4	41.5	28.0	Overcast	0			
5	43.0	28.0	Overcast	1		(177.0)	
6	46.0	29.0	Overcast	0			
7	40.0	28.5	Clear	1		(178.0)	
8	45.0	28.0	Clear	0			
9	46.0	27.5	Rain	1		(130.0)	
10	46.0	28.0	Rain	0			
11	46.0	27.0	Clear	0			
12	49.0	26.0	Clear	1			
13	52.0	26.0	Overcast	0			
14	52.0	25.0	Overcast	0			
15	52.0	24.5	Clear	2	174	176.0	178
16	52.0	24.0	Clear	0			
17	54.0	23.0	Overcast	1			

TABLE 1.—Continued

Date 1949-1950	Mean water temperature (Deg. F.)	Water level (inches)	Weather	Number taken	Sea lampreys Total length (millimeters)		
					Minimum	Average	Maximum
May 18	52.0	19.5	Overcast	0	.....	.....	.....
19	53.0	20.0	Clear	0	.....	.....	.....
20	57.0	19.0	Clear	0	.....	.....	.....
21	59.0	18.0	Clear	0	.....	.....	.....
22	62.0	15.0	Clear	0	.....	.....	.....
23	58.0	15.0	Clear	0	.....	.....	.....
24	63.0	14.5	Clear	0	.....	.....	.....
25	62.0	13.0	Clear	0	.....	.....	.....
26	62.0	14.0	Rain	0	.....	.....	.....
27	56.0	15.0	Clear	1	.....	.....	.....
28	57.0	14.0	Clear	0	.....	.....	.....
29	60.0	13.0	Overcast	0	.....	.....	.....
30	62.0	13.0	Clear	1	.....	(133.0)	.....
31	64.0	13.0	Overcast	2	.....	.....	.....
Total taken and grand average and range of size...				16,235	¹ 103	² 144.7	² 190

¹Trap inoperative during April 18-21 due to extreme flood conditions.²Based on 2,492 specimens.

Most of the individuals observed in migration displayed little effort to accelerate their passage downstream. Such swimming activities as they exhibited were casual and intermittent, and some individuals were seen drifting tail-first. Since the whole movement downstream is passive, the speed of emergence and travel downstream must be attributed to the increased volume and velocity of the stream when such movements occur.

Field observations and laboratory examinations indicate that very few young sea lampreys attempt to feed during migration. An exception occurs where large, inland lakes provide conditions suitable for the parasitic phase. At least two such lakes are present in Michigan. Where smaller inland lakes interrupt the downstream journey, the migrants apparently pass through them without attacking the resident fish species. For example, each year many thousands of recently transformed adults pass through Ocqueoc Lake on their way down the Ocqueoc River to Lake Huron. Since 1947, many fish taken at all seasons of the year from this lake have been examined and none have borne scars that could be attributed to downstream migrants. Furthermore, the examination of digestive tracts of 216 recently transformed individuals taken on November 20, 1948, in the Carp Lake River trap yielded no evidence of their having attempted their initial feeding after transformation.

Were it usual for young migrants to begin feeding before reaching the big lakes, there would be many reports of resident stream fish bearing young sea lampreys or their scars. The few reports received were traceable to native species of lampreys or to sea lampreys carried on fish that had migrated into a stream from a large body of water. Certain exceptions have been noted, however. On May 12, 1948, an examination was made of a 5.0-inch, recently transformed sea lamprey which was taken from a rainbow trout caught in the Ocqueoc River, Michigan,

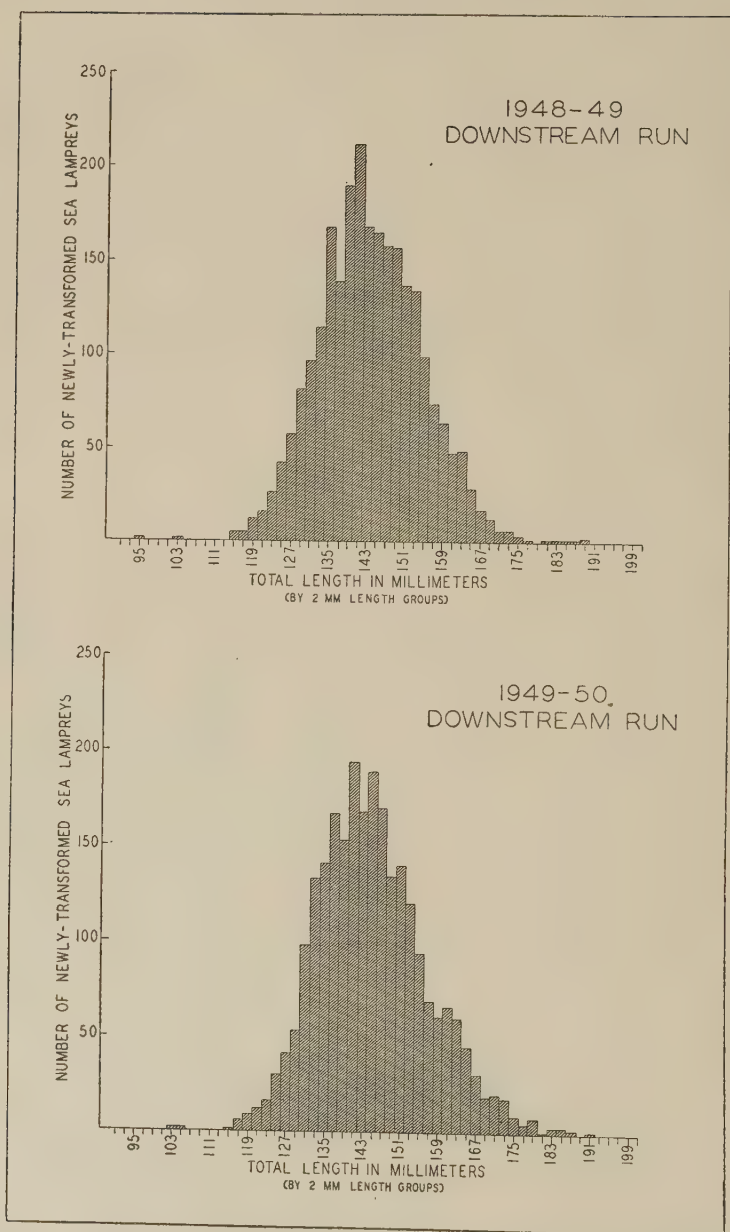


FIGURE 5.—Length-frequency distributions of 2,482 recently transformed sea lampreys taken during their downstream migration in the Carp Lake River in the 1948-49 season and of 2,492 similar individuals taken in the 1949-50 season.

about 5 miles above its estuary. Shetter mentioned four young sea lampreys being found on a rainbow trout caught on July 6, 1945, in the downstream trap of a weir in this river.³ Gage (1928) reported that lake lampreys, kept in aquaria through their transformation, attacked fish immediately after leaving their burrows in the tank bottom. Similar specimens held by the senior author did not feed until some time after emergence. Those exceptions noted for a Michigan stream are attributed to stragglers of the general downstream movement which did not find their way out of the watershed immediately or to individuals which had been to Lake Huron once and rode back into the stream attached to some fish. Examples of this latter behavior were observed in 1949 when on three occasions young sea lampreys were found attached to migrating white suckers taken in the upstream trap of a weir in the Ocqueoc River.

DOWNSTREAM MOVEMENT OF PARTIALLY TRANSFORMED LAMPREYS AND OTHER SPECIES

During the 1948-49 season, 44 partially transformed sea lampreys were taken in the Carp Lake River trap. Ten came downstream in the 1949-50 season and 13 were taken in the 1950-51 season. Most of these individuals were captured in late July and in the month of August. In view of the time of year at which these individuals were taken, their movement downstream may be related to the shift in stream habitat made by some of the larger larvae and transforming individuals (Applegate, 1950). These observations on the scarcity of partially transformed individuals moving downstream are at variance with similar observations made for one other species. It has been reported to the writers that large numbers of incompletely transformed individuals of the Pacific lamprey, *Entosphenus tridentatus*, accompany the major movements of fully transformed lampreys coming downstream during flood stages.

In the 3-year period of operation, a small number of adults and partly transformed individuals of the silver lamprey, *Ichthyomyzon unicuspis*, were trapped. Nearly all were taken in the months of May and June. A few larvae of this species drifted downstream, principally in the months of April and May. Adults of the American brook lamprey, *Entosphenus lamottenii*, were captured almost exclusively from mid-April through the first week of June. One hundred and ninety-seven were taken in the spring of 1949, 115 in the same season in 1950, and 118 during this period in 1951.

A total of 492 larval lampreys identifiable only as sea lampreys or American brook lampreys were taken during the 1948-49 season. This total increased to 8,403 larvae in 1949-50 and 12,647 larvae in 1950-51. A few of these came downstream in nearly every month of the year. The majority, however, were trapped in April and May. The capture

³Shetter, David S. Results of the 1945 operations at the Ocqueoc River sea lamprey weir. Typewr. rept., Rept. No. 1015, Mich. Inst. for Fish. Res., 18 p., 1945.

of both partly transformed and fully metamorphosed American brook lampreys along with the larvae make it seem probable that these larvae were predominantly of that species.

Presumably the American brook lamprey and sea lamprey larvae often occupy the same habitat and during flood conditions many are washed out of their burrows and swept downstream. These displaced larvae are thought to be "total casualties" once they are swept out of the stream and into the lake proper.

In addition to the various lamprey species, 23 species of fish were taken in the trap as they moved downstream. In all, 13,319 fish were caught during the period of trap operation. The principal runs were of white suckers *Catostomus c. commersonnii*, Great Lakes longnose dace, *Rhinichthys c. cataractae*, northern common shiners, *Notropis cornutus frontalis*, lake chubs, *Couesius plumbeus*, smallmouth black bass, *Micropterus d. dolomieu*, and brook stickleback, *Eucalia inconstans*. All but the last species were believed to be spawning-run fish that were returning to the lake. Presumably all had been transferred upstream over the dam at various times during the season.

Of particular interest was the fact that no runs of fishes occurred during the period when the bulk of the newly transformed sea lampreys were coming downstream. Furthermore, during this period downstream movements of resident stream fishes were limited. Of the 13,319 fish trapped in the 3-year period, only 1,798 or 13.6 percent were taken during the period of downstream movement of the young sea lampreys (November 1 to April 30). The remainder (11,521 individuals or 86.4 percent) were taken during the intervening periods when no downstream movement of lampreys was occurring (May 1 to October 31). This fact is of particular significance since it would indicate that devices lethal to all fish life (such as high-voltage electric fish fences), which were designed to destroy downstream runs of newly transformed sea lampreys, would cause little damage among other populations of resident or migrating fish species.

ACKNOWLEDGMENTS

The writers wish to acknowledge the assistance of Mr. Albert Gabrielson, of Carp Lake, Michigan, who was trap attendant during the entire period of operation, and the further assistance of Eda S. Applegate and William Gaylord in making the numerous measurements of collected specimens.

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GAGE, SIMON H.

1928. The lampreys of New York State—life history and economics. Biol. Surv. of the Oswego River System, State of New York Cons. Dept., Suppl. to 17th Am. Rept., 1927, pp. 158-191.
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Part 11
Business Sessions

AMERICAN FISHERIES SOCIETY

EIGHTY-FIRST ANNUAL MEETING

The eighty-first annual meeting of the Society was opened in the Seneca Hotel, Rochester, New York, at 8:30 a.m., Wednesday, September 12, 1951. The agenda were as follows:

Wednesday, September 12

Morning and Afternoon: Joint field trip with the International Association of Game, Fish and Conservation Commissioners, to the Rome State Fish Hatchery and through the Finger Lakes region, under auspices of the New York Department of Conservation.

Evening: Annual Banquet—Grand Ball Room.

Thursday, September 13

Morning: Address of the President; roll call of members; action on nominations for membership; introduction of noteworthy guests and visitors; appointment of sessional committees; reports of officers, chairmen of regional divisions, standing committees and *ad hoc* committees.

Afternoon: Presentation and discussion of papers.

Friday, September 14

Morning: Presentation and discussion of papers.

Afternoon: Presentation and discussion of papers; reports of sessional committees; election of officers, and of committee members subject to election; installation of the new President; concluding business.

OPENING REMARKS OF THE PRESIDENT

THE NEED FOR RESEARCH AS AN AID TO BETTER FISHING

ALBERT S. HAZZARD

It is especially fitting that Rochester should be our meeting place in New York State in 1951. Just 25 years ago the first of sixteen annual surveys of the watersheds of New York was completed under the direction of our beloved past-president, Dr. Emmeline Moore. That survey set the pattern not only for New York State but for many other state and federal agencies throughout the country. It also was the training ground for many fisheries workers.

Another reason why Rochester is an appropriate meeting place for our Society is that one of the fathers of American fish culture, Seth Green, was born near here and in 1864 established his private trout hatchery on Caledonia Creek.

One of the functions of the American Fisheries Society through its standing Committee on Hydrobiology and Fish Culture is to "maintain a continuous survey and appraisal of research and applied work in the fields of aquatic biology—fishery science, fish culture and fishery management . . . and to develop and encourage . . . improvement of techniques . . ." As President of this society I have therefore asked this committee, headed by Dr. Edward Schneberger, to give special consideration to research needs in fisheries as may be sponsored by federal aid and through other sources. This committee is to work closely with a similar committee of the Wildlife Society, recently appointed by Professor Warren Chase, President of that society, to consider needs for wildlife research which may be initiated under the Pittman-Robertson act and otherwise. We believe the reports of these committees may prove helpful to fish and game administrators who may desire to initiate or to expand fish and game research through federal aid funds.

But I am talking as though everyone in this room were thoroughly convinced of the value of fish and wildlife research and wanted to see more money spent on it; and I'll venture that isn't entirely true. Many administrators still feel that research is a frill, a necessary evil, perhaps, in this scientific age, but that developing another fish hatchery or game farm or putting more wardens in the field would be a better use of the sportsmen's license money. There are other administrators who appreciate the value of research but who are afraid to allot any sizeable funds to it for fear of public criticism.

I think that the lack of support for research both from fish and game administrators and sportsmen stems from a misunderstanding of what research really is. No one has done a better job of explaining the meaning of research than Charles F. Kettering, inventor of the automobile self-starter, and until recently vice-president in charge of research for the General Motors Corporation and a past-president of the American Association for the Advancement of Science. The following statement has appeared in several magazines, although I don't know the original source:

"Research is a high-hat word that scares a lot of people. It needn't. It is rather simple. Essentially, it is nothing but a state of mind—a friendly, welcoming attitude toward change. Going out to look for a change instead of waiting for it to come. Research, for practical men is an effort to do things better and not to be caught asleep at the switch. A research state of mind can apply to anything: personal affairs or any kind of business, big or little. It is the problem-solving mind as contrasted with the let-well-enough-alone mind. It is the composer mind instead of the fiddler mind. It is the tomorrow mind instead of the yesterday mind."

There have been a number of criticisms of research, some of them justified, others ill-founded. One of the commonest is that research is impractical and that the results can't be applied to the job of making better fishing and hunting. To many, the researcher is still a professorish-looking individual wildly cavorting over the countryside swinging a butterfly net, or a bookish fellow in a dusty laboratory who continues to pile up more and more data on the number of hairs on the foreleg of a fly. It is the puttering type of professor who has given "pure" research a black name. The conservation administrator rightly wants no part of such and insists that any research done in his outfit be "practical" and yield results which can be applied. I don't think he means "practical" or "applied" research so much as *directed* research, directed along lines which a competent supervisor knows from past experience are most likely to produce results. For example, instead of setting up a project to study the effects of different temperatures on the feeding activities of goldfish he will substitute trout or bass or some other fish of direct interest to the department for which the research is being conducted. The same biological principles of the relationship between the temperature of the environment and body metabolism will be forthcoming but the results can be directly translated to the feeding of hatchery fish or perhaps can be used to explain to some sportsman why his catches have fallen off with a change in weather.

Not that all research need point to some immediate practical objective. Back in the late twenties in Michigan, systematic surveys of the streams and lakes of the state were begun, primarily as a guide to fish planting. Here was a practical objective, it is true, but the man

who directed these surveys was a scientist of broad interests and he early saw that other more important information was coming from the collection of these facts about the lakes and streams. The surveys were showing up vast differences in the fish populations of the waters and he stimulated his assistants to try to find out why this lake was better than the one over the hill or why a particular stretch of river furnished exceptional trout fishing. That and earlier experimenting by his predecessor, the late Dr. Jan Metzelaar, led Dr. Carl L. Hubbs, first director of the Institute for Fisheries Research, to propose full scale research on stream improvement. A husky lad with ambitions toward a Ph.D. took the Institute fellowship on this project and began intensive experiments on different types of streams in Michigan and elsewhere. All sorts of current deflectors, dams and covers were placed in these waters—each device numbered with a copper tag and fully described by field notes. The hundreds of structures were checked by the researcher, Dr. Clarence M. Tarzwell, both winter and summer for a period of five years. Out of this research evolved the present program of stream improvement in Michigan, now the second largest item in our Fish Division's budget. Perhaps even more importantly Tarzwell's research led to the appreciation that watershed management—keeping the soil in place and keeping the vegetative cover intact where possible—is even more important than making additional pools in a stream.

One more example of how so-called pure or fundamental research paid off in Michigan: At about this same time we had just finished a rapidly accelerated program of developing a number of hatcheries and cooperative rearing ponds for raising millions of bluegills and bass for annual restocking of the thousands of lakes of which Michigan boasts. It was "easy money" coming from the federal government through the E.C.W., W.P.A., P.W.A., and other relief agencies. True, we had to provide supervision and some of the materials, but at the time it seemed as though fish management was getting a big boost at little cost to the sportsman. Also about this time we began to realize that there were some pretty big gaps in our knowledge of most of Michigan's principal warm-water game fish—bass, bluegills, pike and walleyes. With no other immediate purpose than to fill these gaps, and hoping it would lead to better management, W. F. Carbine, then of our Institute, began a study of the life history of these fishes. He worked night and day to find out how, where and when they spawned, how many young were produced, what they fed on and what parasites and other enemies threatened their well-being. He didn't get all the answers, of course, but the facts he uncovered coupled with the findings of other workers exposed the futility of stocking bass, bluegills, perch and walleyes for maintenance. Nature was doing such a good job where the fish had any chance at all that man's efforts were puny in comparison and were either not needed or even harmful. Out of

this basic research came facts which saved the Michigan Department of Conservation money which can be devoted to more productive activities.

This same basic investigation raised another significant question. If there were more than enough young perch, bluegills, bass, and the like being produced naturally, were size limits and even closed seasons necessary? Along with some other states and notably in the T.V.A. waters under R. W. Eschmeyer (the man who got Carbine started on his research in Michigan) these theories were given pretty thorough tests on a number of experimental waters. The effects of discarding these regulations were checked by operating creel censuses, to learn what happened to the fishing. Population counts were also made to find out how many fish were there and what percentage of the stock the anglers were actually taking. Results of these inquiries have been good news for anglers and administrators. More fishing for these warm-water fish can be permitted with safety, and laws can be simplified and reduced in number. How far we can go has not yet been determined but directed research will provide reliable answers.

Facts from unprejudiced sources are needed by administrators if they are to be on safe ground in recommending legislation. Too often the information from research is accepted and acted upon only if it confirms present policies. Findings which discredit current fish management practices are likely to be questioned or even disregarded entirely. It is human to desire a good reputation and to dislike change, but progress depends upon constantly adjusting programs to current needs as new methods are developed. Dingell-Johnson funds, though small in comparison with those from Pittman-Robertson, should aid in the development of fishery research in the states and territories. More basic research and carefully controlled experiments are essential to better fishing.

APPOINTMENT OF SESSIONAL COMMITTEES

Time and Place

Marion Toole, Texas, *Chairman*
William E. Ricker, British Columbia
E. A. Seaman, West Virginia
Gordon L. Trembley, Pennsylvania
H. C. Ward, Oklahoma

Auditing

John S. Gottschalk, District of Columbia, *Chairman*
H. Wesley Curran, Quebec
Lyle M. Thorpe, Connecticut

Resolutions

E. B. Speaker, Iowa, *Chairman*
Charles O. Hayford, New Jersey
H. H. McKay, Ontario
Alan C. Taft, California
E. L. Wickliff, Ohio

Nominating

Russell P. Hunter, Connecticut, *Chairman*
Elmer Higgins, District of Columbia
A. G. Huntsman, Ontario
Russell Lord, Vermont
Frederick A. Thompson, New Mexico

Publicity

Udell B. Stone, New York, *Chairman*
C. Willard Greene, New York
Dwight A. Webster, New York

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

GEORGE E. SPRECHER

As Secretary-Treasurer of the American Fisheries Society certain responsibilities have been assigned to me by the Constitution and By-laws of the Society. In addition, the Executive Committee has from time to time extended these responsibilities to cover the special needs of the Society. It may be of interest to the members to learn just what these additional duties are. Following are some of the more important ones:

(1) Provide the Nominating Committee with a list of members who were in attendance at one or both of the two previous meetings of the Society. This list of active members are those eligible to election as officers of the Society.

(2) Provide the Nominating Committee with a list of members in good standing. This list consists of those active members whose dues are not more than 12 months in arrears and who are therefore eligible for election to standing committees of the Society.

(3) Provide the Nominating Committee with information on outstanding work done for the Society by committee members.

During the course of the fiscal year, three meetings of the Executive Committee of the Society were held. Two were held in Memphis during the 1950 annual meeting and one was held in Milwaukee during the 1951 North American Wildlife Conference. Action taken at these meetings included the following:

(1) Allotted the sum of \$250 to cover the cost of an index for the last 21 volumes of the TRANSACTIONS—this work to be done by Dr. Beckman.

(2) Designated the size of the next volume of the TRANSACTIONS at 450 pages.

(3) Instructed the Librarian to maintain one complete set of the TRANSACTIONS.

(4) Approved the circularization of a newsletter suggested by E. A. Seaman.

(5) Authorized the payment of travel and subsistence expense for the President to attend the meeting of the Western Division, and

(6) Approved the joint meeting with the American Society of Limnology and Oceanography for 1951.

Membership in the Society now stands at 1,055 active members, 42 life members, 18 sustaining members, 69 library members, and 35 official members. There was an increase of 116 active members during the past year, and 14 library members. However, there is one less life member and one less sustaining member than last year. A total of 192 members were added during the year and 64 were lost as members of the Society.

FINANCIAL REPORT

The financial statement indicates that the Society is in satisfactory condition as of June 30, 1951. Total receipts for the 1950-51 fiscal year exceeded those of the 1949-50 year by over \$200. The cost of printing two issues of the *TRANSACTIONS* was paid during the last fiscal year which increased total expenditures over the previous year. At the present time our bills are paid in full except for the cost of Vol. 80. This latest issue is being mailed to members at this time. The general fund consists of \$5,738.10 in cash. The permanent fund consists of \$2,206.37 in cash and \$3,462.50 in securities.

In view of the troubled international situation which exists at this time, it is rather difficult to foresee just what the future status of the Society will be. Applications from new members now appear to be leveling off. The costs of conducting the affairs of the Society increase with the rising spiral of inflation. At present we are in good financial condition but I do not believe it is wise to overexpand our activities at this time. Two years ago the Society approved the transfer of \$5,500 from the Permanent Fund to the General Fund to take care of current bills. I recommend that this money be repaid to the Permanent Fund as soon as possible and that expansion of the Society's program which would increase expenditures, be withheld until this is done.

The detailed financial report is as follows:

July 1, 1950—June 30, 1951

GENERAL FUND

Balance on hand, July 1, 1950..... \$6,241.64

Receipts:

Annual Dues		
Individuals		
For the year		
1947-48.....	\$	24.00
1948-49.....		27.00
1949-50.....		355.50
1950-51.....		3,971.50
1951-52.....		85.00
1952-53.....		4.50
		\$4,467.50

State Memberships

For the year	1948-49	\$	.....	
	1949-50		40.00	
	1950-51		1,200.00	
	1951-52		40.00	\$1,280.00

Library Memberships

For the year	1945-46	\$	.....	
	1946-47		.....	
	1947-48		.....	
	1948-49		.....	
	1949-50		20.00	
	1950-51		240.00	
	1951-52		8.00	\$ 268.00

Club Memberships

For the year	1946-47	\$	.....	
	1947-48		.....	
	1948-49		.....	
	1949-50		.....	
	1950-51		180.00	
	1951-52		15.00	
	1952-53		5.00	\$ 200.00

Sale of TRANSACTIONS and Special Publications	\$2,032.35
Sale of Index	2.50

Total Receipts	\$ 8,250.35
Total Receipts, plus July 1 balance	\$14,491.99

Disbursements:

Printing of TRANSACTIONS	\$ 7,118.05
Other printing	359.63
Clerical services—Ann L. Zwick	113.66
Univ. of Michigan	16.40
Postage and supplies	308.59
Editing	110.11
Reporting services	173.00
Rental of meeting room	.....
Contribution to WESTERN DIVISION	50.00
Insurance	69.36
Fidelity bond	18.75
Freight charges	.....
Indexing service (Vol. 78)	.....
Travel Expense—Lloyd L. Smith, Jr.	131.87
A. S. Hazzard	283.47
Miscellaneous	1.00

Total Disbursements	\$ 8,753.89
Total Receipts, plus July 1 balance	\$14,491.99
Total Disbursements	8,753.89

Balance, General Fund, June 30	\$5,738.10
Transfer from Permanent Fund, June 30, 1950	.....
Balance, General Fund, June 30	\$5,738.10

PERMANENT FUND

	1950-51
Balance on hand, July 1.....	\$2,861.24

Receipts:

Individual Life Memberships.....	\$
Patron membership (Perk Foods Co.).....	250.00
Dividend Income	
Consumers Power Company.....	56.00
Central Illinois Light Company.....	13.20
Mortgage Certificates	
Principal Distribution.....	33.33
Income Distribution.....	5.96
Dividend Distribution.....	100.00
Sale of Stock Distribution Rights.....	4.14
Total Receipts	\$ 462.63
Total Receipts, plus July 1 balance.....	\$3,323.87

Disbursements:

Purchase of Government Savings Bonds (\$1,000.00 and \$500.00 Maturity Value).....	\$1,110.00
Printing (Life Membership Cards).....	7.50
Total Disbursements.....	\$1,117.50
Total Receipts, plus July 1 balance.....	\$3,323.87
Total Disbursements.....	1,117.50
Balance Permanent Fund, June 30.....	\$2,206.37
Balance, Permanent Fund, June 30.....	\$2,206.37

RECAPITULATION

	1950-51
Balance, June 30, General Fund.....	\$5,738.10
Balance, June 30, Permanent Fund.....	2,206.37
Balance, June 30, both funds.....	\$7,944.47

SECURITIES HELD, JUNE 30, 1951

(1) New York Title and Mortgage Company, Series F-1	Paid in
Certificate No. 10811.....	full
(2) Title Guarantee and Trust Company	
Certificate No. 103553	\$ 40.00
Certificate No. B-71070	40.00
(3) U. S. Government Savings Bonds	
No. D682395F 8-29-49 (\$500 mature value).....	371.00
No. M1610061F 8-29-49 (\$1,000 mature value).....	742.00
No. D702345F 12-15-50 (\$500 mature value).....	370.00
No. M1703542F 12-15-50 (\$1,000 mature value)	740.00
(4) Consumers Power Company	
No. G-6085, 28 shares at 33 $\frac{3}{4}$	945.00
(5) Central Illinois Light Company	
No. B-1752, 6 shares at 35 $\frac{3}{4}$	214.50
TOTAL.....	\$3,462.50

PROPOSED BUDGET — 1951-52

GENERAL FUND

Balance on Hand July 1, 1951..... \$ 5,738.10

Estimated Receipts

1,055 Active Members at \$4.50.....	\$4,747.50
35 Official Members at \$40.00.....	1,400.00
18 Sustaining Members at \$10.00.....	180.00
69 Library Members at \$4.00.....	276.00
Sale of Publications	2,000.00

Total Estimated Receipts..... 8,603.50

Net Estimated Income..... \$14,341.60

Estimated Disbursements

Printing—Vol. 80.....	\$4,500.00
Printing—Vol. 81.....	4,500.00
Other Printing	400.00
Clerical Services	125.00
Postage and Supplies.....	300.00
Editing	110.00
Reporting Services	300.00
Contribution to Western Division.....	50.00
Fire Insurance.....	70.00
Fidelity Bond.....	18.75
Indexing Service	90.00
Travel Expense	60.00
Miscellaneous	76.25

Total Estimated Expense..... \$10,600.00

Estimated net balance, General Fund, June 30, 1952..... \$ 3,741.60

REPORT OF THE LIBRARIAN

WILLIAM C. BECKMAN

Since the last report was rendered to the Society the supply of five volumes of the *TRANSACTIONS* has been exhausted. Volumes for the years 1911, 1921, 1930, 1932 and 1944 are now entirely sold out.

On August 31, 1950, the overrun of Volume 79 was received and stored. Additional storage space was provided by Colorado A & M College as former storage space was inadequate with the arrival of Volume 79.

From August 17, 1950, to August 15, 1951, 881 copies of *TRANSACTIONS* and 194 copies of "A List of Common and Scientific Names of the Better Known Fishes of the United States and Canada," were sold.

An inventory was taken on August 15, 1951, at which time 3,507 *TRANSACTIONS*, 1,282 Special Publication No. 1, 350 cloth bound Indexes 1872-1928 and 147 paper bound copies of the Index were on hand.

In July, 1951, Mr. Ward T. Bower again sent the Librarian a few copies of back volumes of the *TRANSACTIONS*. Several of these volumes were those no longer available. The Librarian contacted libraries and disposed of most of these volumes. It is believed that the disposal of these hard-to-get volumes to libraries is better than selling them to individuals. Libraries of schools where fisheries work is offered were those selected for receipt of these volumes. The Society is in debt to Mr. Bower for his helpful interest. Work is still in progress on the Cumulative Index, 1929-1949, and it may be ready for distribution by next year's meeting.

Available Volumes of the *TRANSACTIONS* of the American Fisheries Society
as of Aug. 15, 1951

At \$1.00 per volume

1906.....	32	1912.....	52	1925.....	157
1907.....	34	1913.....	83	1926.....	17
1908.....	45	1919.....	48	1927.....	40
1909.....	18	1920.....	28	1928.....	21
		1924.....	75	1929.....	37

At \$3.00 per volume

1931.....	46	1942.....	21	1945.....	81
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At \$4.00 per volume

1946.....	242	1948.....	806
1947.....	779	1949.....	842

Index 1872-1928

Paper bound — 147 — at \$1.00 Cloth bound — 350 — at \$1.50
Special Publication No. 1—1,282 copies—25 cents each

REPORT OF THE CHAIRMAN OF THE
WESTERN DIVISION

JAMES C. SIMPSON

The third annual meeting of the Western Division of the American Fisheries Society was held in Phoenix, Arizona, on April 30, May 1 and 2, 1951. As has been the custom, it met jointly with the Western Association of Game and Fish Commissioners. A continuation of such joint sessions is favored by the membership.

Due to the location of the 1951 convention site, the number of members attending this year's meeting was not nearly as large as the number convening in Seattle in 1949 and in Portland in 1950. In spite of the location and the general tightening of regulations by both State and Federal agencies in permitting out-of-state travel, 41 members were in attendance. It is encouraging to note that each year there has been an increase in the membership in the Society from the Western Division.

It was my good fortune to be appointed by the President and to serve on the Committee on Regional Divisions of the American Fisheries Society. In my correspondence with the Chairman of that Committee, I hesitated to recommend the establishment of other divisions because of my personal unfamiliarity with other geographical sections of the United States. However, I did state, and I take this opportunity in behalf of the members of the Western Division, to report to the membership at large that the establishment of the Western Division has been to the benefit of the Western fisheries workers.

The Bylaws of the Division submitted to the Society in 1950 were not acceptable in the form submitted. After receiving the criticism of the Committee on Constitution and Bylaws, I appointed a committee to redraft the Bylaws. Members of that committee were: A. F. C. Greene, Wyoming; John Gottschalk, Montana; and W. D. Klein, Colorado. The Committee's report was accepted by the Division and the Bylaws have again been submitted to the Society. It is hoped they are now in an acceptable form and will be approved.

Officers elected for the year 1951-52 are: A. W. Yoder, Arizona, Chairman; Clarence Pautzke, Washington, Vice-Chairman; and Fred Thompson, New Mexico, reelected Secretary-Treasurer.

It was the good fortune of the Division to have President A. S. Hazard in attendance at the Phoenix meeting. His helpful suggestions will do a great deal toward the building of a better Division. It is the consensus of opinion among Division members that the President of the Society should be in attendance at each annual meeting of the Division as his guidance can be most helpful in steering the Division to greater accomplishments.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

A. L. PRITCHARD

The past year has seen more interest and activity in the international relationships involved in the conservation and exploitation of the fishery resource. There is now no doubt that purely national outlook and attitude are no longer possible or desirable. The commercial fishing industry has assumed a place of extreme importance with the rise in human population and the resultant demand for protein food and vitamins. Pressure on the stocks has increased. Marketing problems have arisen. Because fish do not respect national boundaries, it is inevitable, if sound conservation and regulation toward sustained production is to result, that we must become more and more international in outlook.

Your Committee on International Relations was established many years ago, before the present trend in interest developed, "to exchange ideas pertaining to the various phases of fisheries administration, biology including fish culture, with foreign biologists, conservation and fisheries administration officials, fish culturists or agriculture societies." A report based on such exchange was to be presented at each regular meeting. It is true that each year such a memorandum has been submitted. At the first the summary covered almost the whole field but each year more and more is omitted, until at the present the report is virtually a summary of those international negotiations with which the members may have had immediate contact. To cover the whole field would be impossible within the scope of time, finances and printing costs available. In addition, in many instances, international relations are often in such a tender stage that they cannot be discussed let alone reported.

It is true that the reports of developments have been informative and of value to the members but, while in the earlier years the intent of the Society's directive was carried out, lately the task has become more and more difficult and in the not-too-distant future will be almost impossible. Already we seem to have departed from the viewpoint of exchanging ideas. Our reports are a recitation of events. We can see the time when even this will be difficult and we will be loading all the work on those whose efforts are entirely in the field of international relations in fisheries.

Your Committee feels that in view of the changing conditions, its duties and responsibilities should be reviewed by the incoming Execu-

tive with a view to determining whether some more specific directions might be laid down or whether we should continue in our present policy, realizing its ever-increasing shortcomings.

Because your Committee favors evolution rather than revolution, it has felt that it should for this meeting continue to review and record briefly for the information of the members, as many as possible of the international activities in the fisheries field during 1950. The material used herein has been collected through correspondence and contact with those people involved. We would particularly pay tribute to Dr. Stillman H. Wright, who last year was Chairman of this Committee and who this year forwarded a great deal of the material.

INTERNATIONAL TECHNICAL COOPERATION

United States

As you are aware, the United States of America has, of recent years, developed a very full program of cooperation with other areas. The Act for International Development authorizing the Point Four Program was approved by the President on June 5, 1950, and on September 6, the first annual appropriation of \$34,500,000 for the fiscal year 1951 became available. On September 8, the Point Four Program became the responsibility of the Department of State by Executive order. The designated agency within the Department is the Technical Cooperation Administration, and Dr. Henry G. Bennett is the Administrator. By June 30, 1951, there were 170 Point Four projects or contracts in force in 36 countries. The following table gives the expenditures authorized for fiscal year 1951, including some funds diverted from sources other than the appropriation noted above:

Multilateral programs:

United Nations	\$12,007,500	
Organization of American States.....	1,000,000	\$13,007,500

Bilateral programs:

Inter-American area	11,256,480	
Near East, South Asia, and Africa.....	5,636,125	
Far East	217,939	

Unallocated geographically:

Technical staff support for field projects and training programs.....	1,115,449	
Equipment not yet allocated to projects..	1,000,000	
Other	1,394,875	20,620,868

Executive direction and administration (including \$340,000 for personnel recruiting, clearance, and training).....

2,177,941

Total Expenditures \$35,806,309

The fishery missions to Peru and Mexico, which were formerly under the program of the Interdepartmental Committee for Scientific and Cultural Cooperation, have been transferred to the Point Four Program.

Fishery Mission to Peru.—The Mission was established in 1949 under the direction of Robert O. Smith, and has had notable success in reaching its objectives. Early in 1951, two additional experts were added to the staff: Norman D. Jarvis, Fishery Products Technologist, for a period of six months, and Charles D. Wade, Fishery Biologist, for an indefinite period. Plans are now being matured for construction of a marine biological laboratory and an exploratory fishing vessel. Two Peruvian students who received a year of instruction in fishery biology in the United States have recently returned to Lima, and it is expected that they will aid materially in development of the program. The critical shortage of meat products in Peru requires increased production of fishery products for domestic consumption.

Fishery Mission to Mexico.—The Mission, which was established in 1942, with Milton J. Lindner as Chief, has continued its work in cooperation with the Mexican Directorate General of Fisheries. In the past decade, there has been a remarkable development in the shrimp industry, with an increase in production from five million to forty million pounds. The *Instituto de Pesca del Pacifico*, an organization financed by industry and the Mexican Government, is now conducting a program for collection of the basic data necessary for development of a program of conservation to insure the maximum sustained yield. Most of the shrimp are exported to the United States, and there is an urgent need for increase in production of species suitable for domestic consumption to improve the diet of the Mexican people with respect to proteins, vitamins, and essential minerals.

Fishery Mission to El Salvador.—The Mission was established in August, 1951, with the assignment of Leroy S. Christey, who will remain in El Salvador for a year or more. Purpose of the project is to determine the existing facilities for capture, preservation, distribution, and marketing of marine products, and the outlook for development of a more effective industry. Attention will also be given to the possibility of development of the inland fisheries. In accordance with Point Four policy, El Salvador will provide a portion of the funds necessary for operation of the Mission.

Future Plans.—Many other projects involving technical assistance to underdeveloped countries are under consideration for fiscal year 1952, but appropriations for the purpose have not yet been made. Pending determination of the availability of funds, it is impossible to foresee the character and extent of the fishery program.

Training Program.—Only one fishery trainee under the Point Four Program is now in the United States, but it is expected that several others will arrive within a year. The Fish and Wildlife Service has cooperated with the Department of Defense and the Economic Cooper-

ation Administration in providing opportunities for foreign leaders in fishery science and administration to visit places and persons of special interest in the United States. It appears likely that visitors of this kind, who remain in the United States about three months will increase greatly in the coming year.

Canada

To most of you, information will have permeated about a meeting held some time ago in Ceylon of the countries making up what is known as the "British Commonwealth of Nations." From this meeting evolved the "Colombo" plan of technical aid under which nationals of certain Far Eastern countries were to come to others such as Australia, New Zealand and Canada for training in the methods of exploiting of natural resources. Technicians from the more highly developed countries were to go to the Far East to aid in organization and administration of the new industries. Already plans have been laid for visits from foreign technicians and one Canadian technician is on his way to Colombo.

INTERNATIONAL AGREEMENTS ON FISHERIES

The International Commission for the Northwest Atlantic Fisheries provided for by the terms of the International Convention for the Northwest Atlantic Fisheries, signed at Washington on February 8, 1949, and entered into force on July 3, 1950, held its first meeting at Washington from April 2 to April 10, 1951. This meeting was devoted primarily to the development of a sound organizational foundation for the future operation of the Commission. Dr. Hilary J. Deason, one of the three United States Commissioners, was elected Chairman for a two-year term and Dr. W. R. Martin of Canada was made Acting Executive Secretary. At the time, five of the original signatory governments had taken action towards ratification, namely, Canada, Denmark, Iceland, the United Kingdom, and the United States. It was anticipated that the remaining signatory governments, France, Italy, Norway, Portugal, and Spain would take action in the near future. Dr. Deason, with his Executive Secretary, is collecting basic information for discussion at the next meeting at which time the various problems involved in the areas outlined will be discussed in greater detail.

The Convention for the Establishment of the International Commission for the Scientific Investigation of Tuna, between the United States and Mexico, was signed at Mexico City on January 25, 1949, and entered into force on July 11, 1950, after exchange of ratifications by the two governments. The United States has appointed the following Commissioners: Mr. Milton C. James, Assistant Director, Fish and Wildlife Service; Mr. Lee F. Payne, Los Angeles, California; Mr.

Eugene D. Bennett, San Francisco, California; and Mr. Gordon Sloan, Astoria, Oregon. With the formal appointment of the Committee, work has now begun on the investigations of the above species of fish.

The Inter-American Tropical Tuna Commission which was provided for under the terms of a Convention with Costa Rica, signed at Washington on May 31, 1949, and entered into force on March 3, 1950, has held two meetings, one at San Diego, California, in July, 1950, and the second at San Jose, Costa Rica, in February, 1951. Mr. Milner B. Schaefer has been appointed as Director of Investigations and assumed his new duties on January 1, 1951. Although the Agreement is open to adherence by other interested governments, to date no such adherences have taken place.

The International Convention for the Great Lakes Fisheries, signed by the United States and Canada on April 2, 1946, has not yet been ratified and it would appear that the outlook for such ratification at the present time is not optimistic. It is true that the scientists on both sides of the border are cooperating rather closely and still continue to have a Sea Lamprey Committee which meets fairly regularly to discuss critical information concerning its program on investigation and control of this species of fish in the Great Lakes. Dr. James W. Moffett, Fish and Wildlife Service, Ann Arbor, Michigan, acts in the capacity of Chairman in this instance. The Lake Trout Committee appears to have held no meetings over the past year or so.

The International Fisheries Commission: As a result of repetition over the years, the Society is well aware of the beneficial effects which have accrued from the work of this body. They know of the present condition of the halibut stocks in the North Pacific. During the year 1950 the Commission was again rather fully occupied with discussions and investigations in an attempt to provide for the full utilization of the halibut stocks and to adjust the method of utilization to the economic demand. While no new provisions were implemented during 1950, it would now appear that agreement is near on certain points. Of particular interest in this connection is the setting aside of two areas off the coast of British Columbia for fishing at a period during the summer after the main season itself had been closed and the quota used. It was hoped that this commercial experiment would give some indication of the availability of fish in these areas at that time and would indicate something of the exploitation.

The work of the *International Pacific Salmon Fisheries Commission* is now well known. It is true that in 1950 the expected Adams River run did not materialize to the extent predicted. On the other hand, we are fortunate that data were available to provide some basis for explaining the non-appearance of the fish. There is no doubt that the work is now producing results which are perhaps best illustrated by

the increasing catches in the early runs to the Fraser during 1951 and by the great increase in escapement to the Stuart Lake and other Upper Fraser areas.

The Aluminum Company of Canada has for the present given up its application for water rights on the Chilko area but has taken up a license for the Nechako-Nanika area in the Upper Fraser watershed. Through the efforts of the staff of the Canadian Department of Fisheries and the International Pacific Salmon Fisheries Commission, this development has been very closely followed. Negotiations are now in progress to provide sufficient remedial measures to alleviate any possible adverse effect from this development.

The Pelagic Sealing (Provisional Agreement): It is perhaps unnecessary to mention the fact that cooperation between Canada and the United States is still being shown in the conservation and exploitation of the fur seals of the North Pacific area. At the present time, under a provisional agreement, Canada and the United States are the only nations involved but it is possible that the Convention will be reopened for discussion.

The United States continues to investigate these mammals and to keep a close check on their numbers. Of course, the actual killing is directly under the supervision of the United States Fish and Wildlife Service.

The *International Whaling Commission* has recently held its meeting in Cape Town, South Africa. Several important problems were on the agenda including the recommendation for the reduction in the minimum legal size limit for certain species of whales. It would appear now that no action will be taken in this connection in the Northern Hemisphere, mainly because sound data were not available to justify the changes. As the Society is well aware the Whaling Commission's investigations are confined mainly to the Antarctic but certain biological investigations have been carried out in California and in British Columbia. These latter have been very important in assessing the effect of the proposed regulations. As a matter of fact, these were the only sound though limited data available.

THE FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS

As the Society is aware, the Fisheries Section of the Food and Agricultural Organization under the direction of Dr. D. B. Finn has been very active during 1949 and 1950.

The third meeting of the *Indo-Pacific Fisheries Council* was held in Madras, February 1-3, 1951. In attendance were delegates from Australia, Cambodia, France, India, Indonesia, The Netherlands, Pakistan, the Philippines, Thailand, United Kingdom, United States, and Viet Nam. The importance of international cooperation in attacking the

problems of the fishing industry were emphasized. There is a general food shortage in the area and the need for increasing the catch of fish to improve the diet is obvious. There is also need for bettering the facilities for preservation, distribution, and marketing. The opportunities for increase in the production of fish in inland waters was evident and the need for dissemination of information among the people was stressed. Perhaps the feature of the meeting was a symposium on stocking of fish with particular reference to rearing fish in ponds and the advisability of increasing the number of ponds for such a purpose.

Fisheries Council for the Mediterranean: A meeting was convened of representatives of several European and Near-Eastern countries in Rome in September, 1949, which agreed on the establishment of a National Fisheries Council for the Mediterranean with organizational studies and functions similar to those of the Indo-Pacific Council. Action is being taken to further this plan with the headquarters being at the Food and Agricultural Organization regional office now in Rome.

Fisheries Council for Latin America: Early in 1950 the visits were made to the Latin-American countries which expressed interest in the formation of a Council for that area. It was planned that the organizational meeting would be held in 1951.

We should stress among the accomplishments of F.A.O. the values of the various publications such as the *Fisheries Bulletin* and the *Handbook on Fish Culture Practices* in Southeast Asia which is now in preparation. The cataloguing of Research and Educational Institutions, the Survey of Fisheries Resources, the Statistical Services, and the Commodity Studies are of great value in bringing together information which serves as a basis for international cooperation.

ADMINISTRATION OF JAPANESE FISHERIES

At the present time with the whole problem of the Japanese Peace Treaty and the various related commercial treaties being discussed throughout the North American continent, it is perhaps inadvisable to make any detailed comments. It should however be pointed out that the whole matter of relationships between Canada, Japan, and the United States in the exploitation of the fisheries is being very carefully studied and it is hoped that an agreement will be reached between the three nations which will be satisfactory if not revolutionary in the field of international agreements.

UNOFFICIAL INTERNATIONAL ORGANIZATIONS

While one should perhaps not mention in these Reports unofficial committees, it is our feeling that we might break precedence to the extent of calling attention to two informal organizations, the *Atlantic*

Fisheries Biologists and the Pacific Fisheries Biologists. A meeting is held each year in the specific area of those people who are directly employed in investigating and administering fisheries on a scientific basis. These gatherings, without the benefit of press reporting and without fear of political implications, cover various phases of scientific investigations. Difficulties and shortcomings are not hidden. It is our opinion that these informal committees, somewhat limited in scope, perhaps more nearly accomplish the original functions set down for our Committee on International Relations. Of course, the reason for this is obvious in that the Atlantic and Pacific Fisheries biologists are a limited group with a localized membership and are not confronted with the problems of a large membership spread over great areas in each district of which specific problems arise and are of particular importance to the local area.

COMMITTEE OF NATIONAL STATE RELATIONS¹

• FRED A. THOMPSON

Perhaps the most important action affecting fisheries during the past year was the passage of the Dingell-Johnson Act by the National Congress and the passage of an enabling act by the various state legislatures. There was one state legislature that failed to take action.

There is a definite trend to make and perpetuate agreements covering state boundary waters. This is particularly noted on the Columbia River, the Mississippi River and some of the rivers and lakes bordering the eastern states. The problem has long been recognized as a sore spot and the continual hammering by fisheries conservation departments is beginning to be felt. It was remarked by many that there still is a long way to go. Many states are hampered by statutes in making satisfactory intrastate agreements; a few legislatures have recognized the need and have given the conservation agency the desired authority.

The water pollution problem is carried on individually by many states but increased activity on this subject is noted as being centered around the U. S. Public Health Service. This agency is assisting the states in organizing compacts of interstate agreements where more than one state is involved. The pollution of waters is prevalent in the industrial areas of the coastal states and the Great Lakes region. The activity of interstate agreements on pollution is not as pronounced in the mountain and plains states and there is a feeling in some instances that these states can take care of their own pollution without outside help or interstate agreements.

¹A detailed compilation of the material from which this report was made is on file with the secretary as part of the general transcript of the meetings.

The President's Water Resources Policy Commission has been received with varying interest. Many of the states made no comment or merely stated that no work had been done on this phase to date. There is some disagreement in the consideration shown for wildlife and recreational values as considered by the commission.

It was definitely noted that the fisheries departments of the coastal states administering the salt water fisheries and the departments administering the inland fisheries tend to be reluctant in coordinating effort. This is perhaps due to a difference of interest; one is concerned with sport and recreational problems, the other with commercial fisheries. At any rate, there is an indication that closer relationship should be promoted particularly on overlapping problems. It is suggested that where fish resources are handled by two independent commissions, serious consideration might be given to the question of placing both fresh and salt water fisheries under one agency.

At least one state mentioned a very great need for uniform fishing codes covering seasons, bag limit, hours and methods of fishing for neighboring states. This need, no doubt, is felt by many others. There are many problems involved in designing a uniform code, but these problems can be minimized by understanding and a desire for coordination. It is quite evident that some codes are established on belief rather than scientific facts and if each specific regulation were analyzed a need for standardization would be revealed.

There is a growing need and demand for National legislation to control the drainage of existing reservoirs that are controlled by agencies of the National Government. The present policy of complete oblivion to the fisheries and recreational requirements in impoundments is playing havoc in the western areas. Compacts and agreements are so written that all of the water from existing federal reservoirs may be used for irrigation as it is needed. These compacts should be rewritten to permit and require a satisfactory dead storage of water.

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

EDWARD SCHNEBERGER

The duties assigned this committee by the Bylaws are very broad and comprehensive. It would necessitate a very long and detailed report to fully comply with the directive and therefore the chairman chose several key subjects for study and assigned an item to each committee member. This report is therefore an abstract of each member's report to the chairman. Pollution was omitted because of the special action taken by the Society at the 1950 meeting.

During the year, President Hazzard asked the committee to study the problem of use of more federal aid funds for basic research. Since only one member responded to my inquiry on this question a committee report at this time is not possible. It is therefore recommended that the subject be reassigned to the committee for next year. The only comments the chairman has to offer are that the need for basic and fundamental research is very obvious and that such research programs need continuity. Many fine programs have been started and then have collapsed because of the lack of a continuing source of funds. Whether or not more Pittman-Robertson and Dingell-Johnson funds should be assigned to basic research is a question that does require considerable study. Continuity of research programs would no doubt receive greater assurance. On the other hand, the profits of years of laborious research are not easily seen by the laymen, who are after all paying the bill. Consequently, if federal aid programs became top heavy with research projects, the same might jeopardize that source of funds. Therefore the only recommendation the chairman can offer is that the question be given considerable more study.

STANDARDIZATION OF TERMS AND PROCEDURES

In view of the fact that certain editorial policies have been laid down and there has been some agitation to have the Society adopt a set of definite standards, a study of this topic was undertaken.

At first it seemed that recommendations for standardization of terms and procedures used in fishery biology and related fields could be easily made. As this task was approached it seemed that obvious misuses, inconsistencies, and bad practices could be pointed out on every hand and consequently, could be corrected by making unqualified recommendations. However, with each listing of the ills of usage, the matter of personal preference, or if not preference then of familiar practice, was found to govern choices and decisions. As each listing was scrutinized it became more and more obvious that the adoption of arbitrary and limited usages, definitions and methods would tend to circumscribe and limit a field of scientific pursuit that needs more, rather than less, "elbow room."

One thing seemed clear at the outset. The standardization of a system of length measurements for fish had been thoroughly gone over and needed little or no expansion. Inches and tenths of inches could be recommended as the universal units without arousing any comment. But, while dwelling upon the application of these units to populations of juvenile fishes, the metric system seemed much more adaptable. Significant length differences among such populations are largely eliminated by the coarseness of a tenth of an inch and it is difficult to measure accurately to the nearest hundredth of an inch. Millimeters and centimeters are definitely better. The same consideration holds where weights are concerned. Several systems of weight measurement have

been proposed, each as the standard with the elimination of all others for the sake of uniformity. Every system has its strong points when the work to be done is the criterion for judgment.

Naturally, many usages of terms, names, definitions, concepts and techniques will bear scrutiny and some possible revision. However, to insist on complete standardization and to recommend for adoption by the Society of many fixed standards would be tantamount to forcing universal acceptance of the personal opinions and interpretations, preferences if you will, of your committee members. It appears to be sounder procedure to point out that standardization will ultimately come about through usage, convenience and recognition of need. Hasty standardization tends to dwarf possibilities of development, evolution and flexibility in that it discourages new ideas. Your committee chooses to recommend certain principles in the form of questions which it hopes will help govern the selection of terms, systems of measurement and procedures for each particular problem or research project:

1. Will systems of measurement yield the highest degree of accuracy and ease in manipulation consistent with the type of work to be done?
2. Are procedures and methods sufficiently well established: to yield consistent results; to be repeated by others; to be located in the literature; to be adequately and clearly described if new and to be adapted to the problems at hand?
3. Is terminology used sufficiently well defined to be clear and comprehensible and to be understood fully by your readers?
4. Is the treatment of the subject matter unduly involved in unnecessary formulations, circuitous discussion and pedantic palaver?
5. Do the terms, symbols, names and measurement units used adequately encompass the extent of your thinking and express the results of your research as you want them understood?

It is believed that adherence to a set of principles similar to these will encourage standardization of terms and procedures without categorically fixing them. Professional and scientific growth of this healthy sort will evolve much sounder foundations than the premature establishment of bases by decree.

UTILIZATION AND HARVEST OF ROUGH FISH AND OTHER SURPLUS FISHES

Since modern fish management methods have stressed greater harvest of rough fishes and surplus game fishes, it was deemed advisable to try to learn what was being done in this respect. Consequently, a survey was made by questionnaire sent to fish management chiefs of 48 states, 10 Canadian provinces and 2 territories. Replies were received from 42 states, 7 provinces and one territory.

Naturally, the first question asked for a classification of game and pan fishes and rough or commercial fishes found in their areas. The replies indicated that almost all members of the families Centrarchidae, Salmonidae, Esocidae, Percidae, and Moronidae were considered game and pan fish. A number of replies indicated that some species of these families under certain conditions enjoyed a dual classification as game or pan fish and as rough or commercial fish. Almost invariably the gars, bowfins, cyprinids, freshwater drum, suckers, whitefishes, shads, and herrings were considered rough or commercial fish where they occurred. Classification of the catfishes was divided. Of the 35 replies listing catfish, 17 listed them exclusively as rough or commercial fishes, 11 classed them exclusively as game or pan fishes, and 7 gave them dual classifications depending upon the species or the area in which they were taken.

Subsequent questions asked for methods of procedure and utilization. An analysis of the subject based on replies to the questionnaire follows:

Most states and provinces (80 percent of replies) are now conducting programs providing for the harvest of surplus rough or commercial fishes through commercial fishing, state supported operations, or state supervised volunteers. Most frequent types of gear used are seines, stationary pots, pounds, lines, etc., gill and trammel nets, and poison.

Most fish management chiefs (72 percent) felt their areas included some waters containing stocks of game and pan fish which were surplus to the needs of the angler; some (20 percent) felt there was no surplus; and a few (8 percent) were undecided. Where surplus populations occurred, 24 were using some private industry or state operation to harvest them, 6 were attempting to encourage more angling, one was destroying spawn, and 11 were taking no action.

A majority (80 percent) of the states in which a surplus population of game and pan fish occurred felt that controlled commercialization would provide better utilization, but a number of them felt that an uninformed public was the chief handicap to putting such a program into effect. This appears to be a major problem facing the fishery administrator today in managing his fisheries to achieve maximum benefit. Education programs and sound demonstration projects seem to be needed to help in this program.

Encouragement of different types of fishing other than hook and line and involving some skill and sport, such as spearing, should also be considered, as well as further development of methods of utilization. In other words, if fish managers can show that sportsmen can have fun in catching these fish and enjoy eating them an army of volunteer workers will help harvest surplus crops.

FARM FISH PONDS

The past decade has shown a phenomenal growth in the interest and management of farm fish ponds. A forum on this subject will "steal the show" at any convention. Stocking ratios, species combinations, techniques of fertilization and balanced populations have been debated at length and it must be recognized that the farm fish pond has contributed greatly to the knowledge of fish management. This subject was pursued to determine, if possible, whether or not sufficient knowledge has been accumulated to give out "kitchen tested recipes" for the management of such ponds. Obviously this is not possible.

The most important factor which contributes to the success or failure of a farm fish pond is the habitat. Since such conditions as surface area, depth, transparency, fertility, bottom type and extent of aquatic vegetation play an important role in determining how a fish population progresses after it is introduced, any variation in one or more of these conditions from one pond to the next would have a good possibility of influencing the success of the stocking ratio used. A stocking combination and ratio which would work well in a pond possessing one set of habitat conditions, will not necessarily be the one which would give the best results in an adjacent pond possessing different characteristics.

Present day knowledge affords the possibility of a choice between two alternatives in overcoming the influence of habitat variations. One of these is the development of a workable stocking ratio for each of the major variations in pond environment. Such a procedure would require the inspection of individual ponds by a qualified person—a desirable practice in any pond stocking program. The second possibility, and the one upon which the bluegill-bass combination as originated in the southeastern United States appears to be based, is the control of the habitat conditions so as to cause them to be as nearly uniform as possible in all ponds. This "standardization" of pond habitats is brought about through a program of chemical fertilization, for the purpose of controlling pond fertility (food production), aquatic vegetation, and water transparency.

If the most sensible approach to the problem of maintaining proper balance of the fish population lies in this type of control of the pond environment, the need for the development of more satisfactory methods for population and habitat management should be emphasized.

Another approach to a successful pond management policy may be along the line of population manipulation. This suggests the possibility that improvements in stocking procedures for the presently used species of pond fish have advanced as far as is practical, and that management to be effective after the fish have matured and spawned, must be based

on reduction of over abundant species and restocking of species showing evidence of depletion, or improvement of environmental conditions so as to favor their multiplication.

Regardless of the fishing site, be it a farm fish pond or in the sea, the angler likes to catch a big fish. It is also an axiom that the angler successful in catching a large fish, in season of course, never sneaks home through the alley. Some states are attempting to route the angler home via the main street by use of the channel catfish in farm fish ponds. Kansas, for example, reports that catfish stocked in ponds have attained 6 pounds in weight by the end of their third year of life and that even greater growth is possible. It appears that, with the predator-prey and overpopulation problem ever existent, utilization of this and similar species is well worth consideration by farm fish pond managers. The inability of catfish to reproduce in most ponds might be a decided advantage in management as well as in research in developing methods of management.

IMPROVEMENTS IN CULTURE OF COLD WATER FISHES

Improvements in the techniques of rearing cold water fishes have been greatest, perhaps, in the field of disease control. Chemicals are now used not only therapeutically but prophylactically. Sulfonamides assist in combating bacterial infections which formerly wiped out entire hatchery stocks. New antibiotics have been employed successfully in the treatment of other bacterial infections. And the refinement of the technique of application of certain chemicals has been placed in service to lighten the hatcheryman's work.

It is only in recent years that prophylactic treatment of fishes has been developed. Many trout and salmon hatcheries on the west coast are troubled with a bacterial gill disease. This disease is usually associated with overcrowding and has been successfully prevented by weekly or bi-weekly treatments using Roccal and pyridylmercuric acetate. These chemicals are used as a prolonged pond treatment for one hour at a concentration of 1:500,000. Treatment is usually necessary through the summer months or period of highest water temperatures. Pyridylmercuric acetate or P.M.A. is also used to control some external parasites.

Furunculosis, a bacterial disease and an early scourge of fish hatcheries, is now fairly well controlled by sulfa drugs. Ulcer disease and other bacterial infections are also controlled with sulfonamides. Most recently, ulcer disease has been cured with terramycin. Aureomycin promises to be of value in controlling fish diseases also.

The development of the prolonged treatment method for the control of ectoparasites has been extremely valuable to fish culturists. The use of fungicides such as malachite green has recently been extended because of the improved method of application. Fungus attacking incu-

bating eggs can be successfully controlled through semi-weekly introductions of malachite green into the water flowing over the eggs. Simple, efficient procedures have been devised for prolonged treatments so that hatcherymen lose very little time in using them and because of this readily accept this means of disease control.

The perennial search for cheaper fish foods continues with little being accomplished. Some of the minimum food requirements for rearing healthy fish have been established but much research remains to lower the cost of artificially feeding fish. The inclusion of a wider variety of materials in trout diets has helped to reduce feed "breaks." In some areas, new and heavier grinding equipment has reduced the labor in preparing feeds but further improvement can yet be made.

In this regard it is hard to understand why greater advances in the field of fish nutrition have not been made. The employment of a nutrition specialist, even at a very substantial salary, might be a very sound and economical procedure for any agency engaged in the culture of cold water fishes.

The value and place of hatcheries in fisheries management is rapidly becoming more clearly understood. Extensive studies on the returns from hatchery reared fish have clearly demonstrated how wasteful and even detrimental artificial propagation can be when improperly used. In the State of Washington for example, the trout hatcheries are managed within the Fisheries Management Division under almost direct supervision of field fisheries biologists whose primary function is to provide as much sports fishing as possible. As a result only trout which can be successfully used are placed in the hatchery for rearing. Overall fishing success has been tremendously improved with a program involving less than one-half the total numbers of fry and fingerling reared five years ago. Research, management, and fish culture cannot be too closely coordinated.

ADVANCEMENT IN TRAINING AND EMPLOYMENT OF FISHERY AND AQUATIC BIOLOGISTS

Analysis of this topic seemed to be a very logical function of this committee and it is regretted that more time and space cannot be devoted to the subject. Perhaps future committees can develop it further.

One of the oldest institutions offering formal training in fisheries is the Washington School of Fisheries. Consequently, a brief review of that institution is in order.

The School of Fisheries of the University of Washington in Seattle was founded in 1919. At that time the fisheries of the Northwest were in a period of expansion and greater exploitation was the chief aim of the industry. It was decided that the school should train students for the commercial fishing industry. Therefore, most of the courses given were in technology or canning and preserving techniques, and

fishing operations and methods. Basic courses in zoology, ichthyology and chemistry were also given. The Director of the School at that time was John N. Cobb, who died in 1929.

After his death Dr. W. F. Thompson, at that time serving as Director of the International Fisheries Commission, was made Acting Director of the School of Fisheries. His primary interest was in biology and, under his leadership, all training in fishing and canning techniques was dropped and a new curriculum was adopted in the field of fisheries biology and conservation. It had become evident by this time that the supply of fish in the Pacific Northwest was not inexhaustible and that depletion of many species was taking place. Conservation was beginning to be recognized as necessary to the continued well-being of the industry, and a change in the objectives of the school was inevitable.

Shortly after the World War II, Dr. Thompson was succeeded by Dr. W. N. Chapman as Director. After spending a year reorganizing the school, Dr. Chapman took leave of absence to act as Special Assistant in Fisheries to the Under Secretary of State and Dr. Richard Van Cleve became Acting Director in 1948.

During recent years it has become evident that people trained in technology are needed in the fishing industry. Therefore, instruction in processing and fishing methods is being developed in the school at this time.

Most students enter the Fisheries School after two years of university preparation in the basic sciences of zoology, chemistry and mathematics, with bacteriology and additional chemistry substituted for some zoology in the preliminary training of technologists. A course of lectures by leading workers in the various research organizations is also given during the preparatory phase to aid students in orienting themselves in fisheries work.

Fisheries training begins in the student's third year with a year's training in comparative anatomy, physiology, and classification and identification of fishes. A year's course is also offered in the classification, life histories, distribution, culture, and methods of capture of commercial invertebrates. These two courses form the foundation upon which all subsequent work is built. More advanced students are offered a year's course in the general biology of fishes, including migration and interrelationships of fish populations; the reproduction, larval and post larva life of marine fishes and the relation of hydrographic conditions, food, etc., to the distribution, abundance and availability of various species of fish. This is followed by a year's course in the more mathematical phases of fisheries biology, including population growth and enumeration, population dynamics and the influence of natural and artificial factors on variations in yield.

A year's course is given in the field of freshwater fisheries biology, which covers methods of hatching, rearing, collection and incubation of salmonoids and related problems, nutrition and diseases of fish and finally the problems of management of freshwater fisheries.

In the field of technology, a year's course is offered which covers the application of chemistry, biology and engineering to the canning, curing and freezing of fish and shellfish and to the preparation of fish by-products, oils, meals, etc. Another course is given through a series of lectures by authorities in the various fields of the fishing industry. As equipment and facilities become available, additional technological training of a more advanced character will be offered.

The research staffs of many of the government agencies, such as the International Fisheries Commission, Washington State Fisheries Department, Washington State Game Department, U. S. Fish and Wildlife Service and the University of Washington Fisheries Institute, are located either on the campus or near by. Most of the research problems of graduate students form parts of the program of these agencies. This gives the students opportunity for part time or summer work and contact with practical work in their selected fields.

The school has recently moved into a new building which has adequate modern facilities for class work and fish collections. A small freshwater hatchery with outdoor rearing ponds has been constructed along with constant temperature facilities and salt water aquariums. An isolation room for study of fish diseases and rooms for microscopic technique and projections of slides and movies are included. A library containing all of the fisheries literature in the university is now housed in this building.

At present there are 127 students in the school. This includes 24 graduate students, 49 seniors, 20 juniors, 8 sophomores, and 26 freshmen.

A great many factors influence the rate of employment of any specialized group. Wars, depressions, need and availability are only some of the factors involved. Nevertheless a survey of the number of biologists employed in 1940 and in 1950 provided some very interesting facts. For the United States, including both state and federal employees both permanent and seasonal, there were 201 employed in 1940 and 684 in 1950. For the Canadian provinces and government there were 20 in 1940 and 68 in 1950. Honolulu reported 0 and 3 respectively. The grand over-all total stands at 221 and 755 respectively.

In conclusion, the chairman expresses his appreciation to the members of the committee for their cooperation during the past year.

COMMITTEE ON COMMERCIAL FISHERIES

RICHARD S. CROKER

Commercial fishing remained at a high level of productivity during the past year. On the whole high prices continued to stimulate activity.

The menhaden of the Atlantic and Gulf Coasts held its place as the top fishery insofar as volume is concerned.

The West Coast tuna industry broke all records with a pack of about nine million cases in 1950. The local albacore run was the heaviest on record and tropical tuna fishing was also exceptionally good for the high seas fleet. Production in 1951 has been held down to let the market absorb this heavy output. An increase in the tariff on canned tuna to 45 percent on January 1, 1951, helped curtail heavy importations from Japan and Peru. Increasing shipments of frozen tuna from these countries, however, have handicapped the operations of the American fishermen. A campaign to enact a tariff on frozen tuna has been started.

Imports of frozen fillets have had adverse effect on the New England trawl fisheries, an effect also reflected in the Pacific Coast bottom fisheries. The principle of free trade may be fine in theory but it has worked a great hardship on the American fisherman whose standard of living and entire livelihood are threatened by foreign competition.

The shrimp fishery still holds the spotlight as the most spectacular development of recent fishery history. There seems to be no limit to the American appetite for frozen shrimp (or prawn if you prefer). Gulf Coast and Mexican production have continued at high levels. Tension between Gulf and Mexican fishermen has eased and there have been no "international incidents." In fact the Gulf and Mexican producers have taken concrete steps toward forming an international association. Panama has recently entered the expanding shrimp fisheries.

The Pacific sardine fishery has remained in the doldrums. Although catches last season were heavy in Southern California there was little activity in Northern California and no fishing whatsoever in the Northwest. The inter-agency cooperative sardine investigation has gotten into high gear and the research staffs are uncovering many facts which have a bearing on the failure of the northern fishery.

The lamprey menace in the Great Lakes fisheries is unabated. However, control methods are being formulated. The spectacular nature of the lamprey's depredations has focused attention on the problem and has made it easier to obtain appropriations for control.

The State of Maine has inaugurated an industry-wide campaign to publicize Maine sardines. A special state agency, financed by a special cannery tax, has been established to promote sales. Dick Reed, the popular and efficient Director of Fisheries for the state, has resigned from that position to take over the leadership of the new project.

Friction between sport and commercial fisheries interests has continued in many places where the two conflict. Additional restrictions have been imposed on commercial salmon fishermen in the Columbia and Sacramento rivers. Feelings have been bitter along the Southern California coast and neither faction is well satisfied by compromise measures adopted by the State Legislature. A state of open warfare exists in the striped bass fishery of the Potomac River right at the doorstep of the nation's capitol. In most places, responsible leaders among both the sportsmen and the fishing industry have done a good job in attempting a rational harvest of the fisheries resources, but the "radicals" on both sides are forever getting out of hand with their appeals to emotion. It has become an inescapable fact that there just are not enough fish to go around for everyone.

Showing that the sport and commercial fishermen can work together for the good of the fisheries when confronted with a common menace, all factors concerned were successful—at least for the time being—in heading off several dam building projects that would have destroyed valuable salmon runs. A destructive power dam on the Cowlitz River in western Washington has been forestalled, and appropriations were disapproved for dams that would have ruined the Columbia River. These and other dams will be promoted again, and only alert and vigorous opposition to them, supported by accurate facts and figures, can keep our salmon runs alive. The rivers of British Columbia and Alaska are also under constant threat.

It is with real regret that we announce the sudden death last October of Alvin Anderson, Director, Washington State Department of Fisheries. His post has been filled by Robert J. Schoettler.

COMMITTEE ON NAMES OF FISHES

REEVE M. BAILEY

At the Memphis meeting this Committee listed the species of fishes for which changes in common names had been requested. Then, and again in the Society's autumn news letter, members were urged to contribute to the discussion on these proposed changes. The opinions and views received in response to this request have been most helpful and are much appreciated by the Committee. All petitions for emendations together with the comments by members were mimeographed and distributed to the Committee in order to provide a sound basis for voting. In the balloting some Committee members withheld opinion on certain names pending more information. For this reason decision on 8 names is postponed until next year. Of the remaining names, the Committee

decided that 8 should be retained as in the published list¹, that 10 be changed, and that 1 be deleted. Also, one species is approved for addition to the list.

After study of the evidence presented there appear to be inadequate grounds for change in the names of the following:

NUMBER IN LIST	PRESENT COMMON NAME, TO BE RETAINED	SCIENTIFIC NAME
146	RIVER CARPSUCKER	<i>Carpiodes carpio</i>
253	SILVER HAKE	<i>Merluccius bilinearis</i>
264	AMERICAN PLAICE	<i>Hippoglossoides platessoides</i>
270	SUMMER FLOUNDER	<i>Paralichthys dentatus</i>
273	FOURSPOT FLOUNDER	<i>Paralichthys oblongus</i>
286	GEORGES BANK FLOUNDER	<i>Pseudopleuronectes americanus dignabilis</i>
289	WITCH FLOUNDER	<i>Glyptocephalus cynoglossus</i>
321	LITTLE TUNA	<i>Euthynnus alletteratus</i>

Retention of each of these names was approved by unanimous choice of the voting members of the Committee, or with not more than one dissenting vote.

Several names adopted on the original list are generally unsatisfactory, and after thorough reconsideration by the Committee the following changes are approved:

NUMBER IN LIST	NEWLY APPROVED COMMON NAME	SCIENTIFIC NAME
145	QUILLBACK CARP-SUCKER	<i>Carpiodes cyprinus</i>
147	HIGHFIN CARP-SUCKER	<i>Carpiodes velifer</i>
156	HUMPBACK SUCKER	<i>Xyrauchen texanus</i>
216	NORTHERN PIKE	<i>Esox lucius</i>
226	BLACKSTRIPE TOP-MINNOW	<i>Fundulus notatus</i>
227	VARIEGATED CYPRINODON	<i>Cyprinodon variegatus</i>
228	DESERT CYPRINODON	<i>Cyprinodon macularius</i>
283	YELLOWTAIL FLOUNDER	<i>Limanda ferruginea</i>
368	YELLOW WALLEYE	<i>Stizostedion vitreum vitreum</i>
369	BLUE WALLEYE	<i>Stizostedion vitreum glaucum</i>

¹1948. A list of Common and Scientific Names of the Better Known Fishes of the United States and Canada. Special Publication No. 1. American Fisheries Society.

Rejection of the previously listed names was unanimous or with no more than 1 or 2 dissenting votes, and at least 5 members of the Committee voted in favor of each of the newly approved names except number 368. For that fish several names were suggested. A preferential ballot showed yellow walleye, walleye, doré, and walleyed pike preferred in that order. The Committee therefore recommends adoption of yellow walleye for *Stizostedion vitreum vitreum*. It may be noted that the vernacular "walleye" may be applied to the species as a whole, to include both *S. v. vitreum* and *S. v. glaucum*.

Largely on the basis of evidence presented by Dr. A. G. Huntsman, to show that *Salmo salar sebago* lacks any basis in fact, it being not genetically different from the sea-run Atlantic salmon, the Committee voted to remove this subspecies (number 109) from the list. In order to permit designation of the lacustrine phenotype of the Atlantic salmon, the name LAKE ATLANTIC SALMON is added as coequal with ATLANTIC SALMON for *Salmo salar* (number 108).

By unanimous vote the Committee decided to employ the spelling "char" in preference to "charr" for *Salvelinus alpinus* (number 117).

Fundulus notti was approved for addition to the list (as number 226a) with the common name STARHEAD TOPMINNOW. (This species, including three or more subspecies, is known also as *Fundulus dispar* and as *F. lineolatus*.)

Requests for a number of further changes have been received during the past year. The membership is urged to advise the Committee in order to provide an adequate basis for reconsideration. Information that is especially helpful includes geographic distribution of the various names for any species, prevalence of use, and class of users. Is a name employed by sport fishermen, in the commercial industry, by biologists, or by whom? The common names to be restudied are:

Number in list	Currently approved name	Suggested substitute name
91	skipjack	river herring or golden herring
104	silver salmon	coho salmon
105	red salmon	sockeye salmon
107	king salmon	chinook salmon
474	rosefish	ocean perch

The question has been raised as to whether or not the practice should be adopted of capitalizing the approved common names of fishes, as is done in ornithology. The reaction of the membership to this proposal is solicited.

The above remarks conclude the formal report of the Committee on Names of Fishes. However, I have a matter of related business which may perhaps best be introduced now. It is transmitted through me at the request of the President of the American Society of Ichthyologists and Herpetologists, Dr. George S. Myers of Stanford University.

The list of common names of fishes of the American Fisheries Society has already served a useful purpose and will, presumably, be even more important in future revised editions. Would it not have even more weight and authority if its decisions were also backed by the American Society of Ichthyologists and Herpetologists? Both Dr. Myers and I feel that it would. However, the American Fisheries Society began the project, has carried it along, and has paid for the publication of the list. This leadership should continue.

Dr. Myers' suggestion is that the A.S.I.H. might aid in the achievement of the objectives of our Committee by having its own Committee on Common Names, to consist of the same persons who are on the A.F.S. Committee. Thus, both organizations together with their respective publications, would adopt the same nomenclature. Most members of the A.F.S. who are eligible candidates for membership on the Committee on Names, including all incumbents, are also members of the A.S.I.H. Since in the A.S.I.H. the President is empowered to create and appoint committees there is no technical barrier to establishment of the proposed group.

The contribution of the A.S.I.H. would rest on its added prestige. That organization would assume no financial responsibility in publication of the list, at least not without authorization from its Board of Governors at one of the annual meetings of the Society.

Section 15 of the By Laws of the A.F.S. states that the Committee on Names "shall coordinate its activities with those of other societies and organizations throughout the world." I feel that Dr. Myers' proposal is in keeping with this directive.

If the A.F.S. approves creation of a Committee on Names in the A.S.I.H., Dr. Myers will act at once to formalize the committee.

Mr. President, I move that this Society approve Dr. Myers' proposed plan.

[The motion was seconded and passed.]

MEMBERSHIP COMMITTEE

W. J. K. HARKNESS

I wish to thank the members of my Committee, and also many other members at large of the American Fisheries Society, for their active cooperation during the past year, in contacting many individuals and groups throughout the United States and Canada who are interested in fisheries work and acquainting them with the work of the American Fisheries Society and the value of the *TRANSACTIONS* as a reference medium for information on progress in fish culture.

During the past year the members of my Committee were urged to place special emphasis on extending our contact with university and other libraries, individual sportsmen and sportsmen's associations, and commercial fishermen. There are, among these groups, many who we believe, would be interested in activity of the Society but who have not been aware of the importance of this work in relation to their own interest and activity.

I may say that the undertaking to contact these groups has not been in any way completed, but may be considered to be only now under-

way, and there is a very wide field for extension of our membership among these, and probably other individuals and groups who would add much value through participation in the work of the Society.

The Secretary-Treasurer advises me that we have accepted 192 new members since the last meeting, 64 have dropped their membership, so that our present membership is 1,219 representing a gain of 116 over last year.

PROGRAM COMMITTEE

DWIGHT B. WEBSTER

Since the report of the Program Committee is in a sense embodied in the schedule of papers and reports to follow, it may suffice at this point for the Chairman to express his appreciation for assistance given by members of the Committee and his hope that the extent and variety of the papers presented may meet with the approval of the Society.

REPORTS OF AD HOC COMMITTEES

COMMITTEE ON REGIONAL DIVISIONS

GEORGE W. BENNETT

The Constitution of the American Fisheries Society, paragraph 1, Article VI, states: "A regional division of the Society may be established by the favorable action of the Society, pursuant to paragraph 4 of Article IV, upon a petition presented to it at any regular meeting by not less than twenty-five members of the Society in good standing resident in a particular geographic region."—Report of the Committee on Revision of Constitution and By-laws, 1949, Trans. Amer. Fish. Soc. Vol. 79, p. 287.

At the Memphis meeting of the Society (1950), the president was instructed by resolution to appoint a special committee on regional divisions. The purpose of this committee was to study the desirability of such regional organizations and the needs, and to prescribe desirable boundaries in the event such divisions are considered essential.

The committee appointed by President Hazzard consisted of George W. Bennett, chairman (Illinois), Willis King (Tennessee), John F. DeQuine (Florida), James C. Simpson (Idaho), K. H. Doan (Manitoba), C. N. Lloyd (Wisconsin), George W. Davis (Vermont), and Gustave Prevost (Quebec). Committee members have corresponded with members of the Society in their own regions regarding the desirability of regional divisions and possible locations of division boundaries.

Most of the Society members approached by the committee were undecided about the desirability of regional division and fully half were more or less opposed to them.

The reasons for opposition were that there were already too many meetings requiring time away from local problems and that strong regional divisions might weaken the parent organization. Several Society members interviewed by the members of the committee stated that their chances of attending regional meetings were no better than attending national meetings.

The basis for establishment of regional divisions of the Society is now a part of the Constitution; one region (Western Division) is now fully organized and there are two others in the process of organiza-

tion. Unless the parent organization decides to strike paragraph 1, Article VI from the Constitution, the movement for regional divisions may be expected to continue.

Boundaries for regional divisions might be recommended on the basis of a regional similarity of fisheries problems and interests which in turn is related to climate, topography, rainfall, and soils. This basis for setting boundaries has much in its favor, if the divisions are not allowed to become too large or too small. If they become too large there is danger that the regional meeting will supplant the national meeting. Members on limited travel allowances will weigh regional meetings where the discussion is wholly on subjects of regional interest, against national meetings where the interest is diversified. Too often the choice will be made in favor of the regional group.

If the regions are too small, the active professional members of the Society within these regions may be too few to develop an interesting program. Therefore, if we are to have regional divisions, it seems logical that the groups should be intermediate in size and where possible, boundaries should be based on a homogeneity of interests.

Proposals have been made to divide the continent into four, five, and six regional divisions. In the 4-region arrangement the divisions would probably be as follows:

NORTHEASTERN DIVISION

Ontario (dual membership with
Northcentral Division)

Quebec

Newfoundland

New Brunswick

Nova Scotia and Maritime
Provinces

Maine

New Hampshire

Vermont

Massachusetts

Rhode Island

Connecticut

New York

New Jersey

Delaware

Maryland

District of Columbia

Pennsylvania

W. Virginia

SOUTHEASTERN DIVISION

Kentucky

Virginia

Arkansas

Tennessee

N. Carolina

S. Carolina

Oklahoma

Louisiana

Mississippi

Alabama

Georgia

Florida

Texas

NORTHCENTRAL DIVISION

N. Dakota	Illinois
S. Dakota	Michigan
Nebraska	Indiana
Kansas	Ohio
Minnesota	Saskatchewan
Iowa	Manitoba
Missouri	Ontario (Dual membership)
Wisconsin	

WESTERN DIVISION

British Columbia	Utah
Alberta	Colorado
Washington	California
Oregon	Arizona
Idaho	New Mexico
Montana	Northern Provinces of Mexico
Nevada	

This plan for four regional divisions is favored by some members of the committee. Others believe that the Western and Southeastern divisions are too large and the diversification of interests in such divisions might approach that of the parent society. Moreover, travel distances within these two divisions could easily equal that to the national meeting.

A 5-region proposal suggested the removal from the Western Division of the southernmost states, the lower half of California and northern Mexico and their union with Texas and Oklahoma to form a Southwestern Division composed of:

Southern California	Texas
Arizona	Oklahoma
New Mexico	Northern Mexico

Very few committee members favored this arrangement. A proposal for six regional divisions placed Kansas and Missouri from the previously listed Northcentral Division, together with Arkansas, Louisiana, Oklahoma, Texas, and Coahuila, Mexico, and boundary provinces eastward into a single Southcentral Division. A Southwestern Division was to be formed by splitting off the following states and provinces from the present Western Division:

California	Arizona
Nevada	New Mexico
Colorado	Northwestern Provinces
Utah	of Mexico

Under the six division plan the regional divisions might be listed as follows:

NORTHWESTERN DIVISION

British Columbia
Alberta
Washington

Oregon
Idaho
Montana
Wyoming

NORTHCENTRAL DIVISION

Saskatchewan
Manitoba
Western Ontario
N. Dakota
S. Dakota
Nebraska

Iowa
Minnesota
Wisconsin
Illinois
Michigan
Indiana
Ohio

SOUTHWESTERN DIVISION

California
Nevada
Utah

Colorado
Arizona
New Mexico
Northwestern Mexico

SOUTHCENTRAL DIVISION

Kansas
Missouri
Oklahoma

Texas
Northeastern Mexico
Arkansas
Louisiana

NORTHEASTERN DIVISION

Eastern Ontario
Quebec
Newfoundland
New Brunswick
Nova Scotia and Maritime
Provinces
Maine
New Hampshire
Vermont

Massachusetts
Rhode Island
Connecticut
New York
New Jersey
Delaware
Maryland
District of Columbia
Pennsylvania
W. Virginia

SOUTHEASTERN DIVISION

Virginia
Kentucky
Tennessee
N. Carolina

S. Carolina
Mississippi
Alabama
Georgia
Florida

It is the consensus of opinion of the committee that the Society should accept either the four-region or the six-region plan presented by the committee. In the latter plan the regions are probably of a minimum size for efficient functioning, travel distances are reduced, and there is less likelihood that the activity of any one of these smaller organizations could seriously weaken the parent organization.

Within the past few weeks the chairman has received a copy of a letter from Dr. S. L. Hora of Calcutta, India, in which Dr. Hora asks an opinion on the formation and affiliation of a branch of the American Fisheries Society in India. While this opinion might conceivably fall within the scope of duties of the Committee on Regional Divisions, it is the suggestion of the committee chairman that the matter be referred back to the Executive Committee for action, and, if their opinion is favorable, that the constitution be modified to specifically state the requirements for regional divisions of the Society located outside the limits of the United States and adjacent Canadian and Mexican Provinces.

COMMITTEE ON PUBLICATION OF A PERIODICAL JOURNAL

RALPH HILE

In our report we shall consider not only the recommendations embodied in the resolution adopted at the Seventy-ninth Annual Meeting which authorized the establishment of this committee but also those contained in a similar resolution passed independently by the Western Division at its Third Annual Meeting. Although both resolutions called for the establishment of a periodical journal, they differed in their proposals concerning the TRANSACTIONS. The resolution passed by the parent society advocated the journal as supplemental to the TRANSACTIONS, whereas the Western Division recommended that a journal be substituted for the TRANSACTIONS. We can dispose of this discrepancy readily with the statement that this committee opposes categorically any proposals for the discontinuation of the TRANSACTIONS. Our report, therefore, will be confined to the consideration of the desirability and feasibility of establishing a periodical journal (presumably quarterly) to supplement the publication facilities now provided by the TRANSACTIONS.

The principal arguments advanced in favor of the establishment of a quarterly journal are: present publication facilities are inadequate; the time between the submittal of the manuscript and the appearance of the printed article will be shortened; the interest of the members will

be maintained better if they receive publications more frequently. The last of these three arguments may have some validity; the first two cannot be supported by the facts.

The statement in the resolution under which this Committee was established that the "... present annual TRANSACTIONS are insufficient to provide for the publication of all worthy technical papers presented for publication," is completely incorrect. The size of every volume since Volume 76 has been limited only by the number of manuscripts suitable for publication. Indeed, the last four volumes would have been even smaller but for the special efforts of the Editors who solicited materials and also spent long, tedious hours re-working articles that should, and normally would, have been rejected as too poorly prepared. The TRANSACTIONS, then, are more than adequate to meet our present needs; furthermore, the size of the volume can be increased substantially to meet increased requirements.

Equally erroneous is the view that a journal would lead to a more rapid publication of manuscripts. Those who hold it are sadly uninformed as to the manner in which periodicals are published. Actually, no editor could operate comfortably without a reserve of material sufficient for at least two numbers. Furthermore, the time lag between receipt of copy and publication is seldom less than nine months in any scientific periodical and often it is greater, particularly for the longer articles. In this respect, therefore, a journal would have little, if any, advantage over the TRANSACTIONS.

Even if a present need for a periodical journal were established, we should be faced with a most difficult task of financing the publication. The framers of the resolution that authorized our committee demonstrated scant knowledge of the costs of printing when they stated so optimistically that "... the financial status of the Society appears to be adequate ..." for the support of a journal. An estimate obtained early this year from the printer of Volumes 76, 77, and 78 of the TRANSACTIONS indicated that the printing, binding, and distribution of 2,500 copies of a 96-page issue done in a format similar to that of the *Journal of Wildlife Management* would cost not less than \$2,000. For a quarterly journal the annual figure amounts to \$8,000 or \$3.20 per subscription. At our present annual dues we should have remaining from each active member only \$1.30 as his contribution toward the publication of the TRANSACTIONS and the operating expenses of the Society. To be sure, the higher dues of State and sustaining members would add to the available funds, but the amount would be far from adequate. Information obtained from other sources shows these cost estimates to be generally sound, though possibly a little low. Certainly, they would prove to be low if the operation of a journal were found to require the services of a full-time secretary to the Editor, and it is difficult to see how the hiring of a paid assistant could be avoided.

It should be stressed that the figures just given assumed a membership of 2,500 — approximately twice our present enrollment. Should we attempt to issue a journal in editions numbering much less than 2,500, the unit cost would be prohibitive. It can be stated unequivocally that the Society's membership must be at least doubled before the establishment of a quarterly journal can be held a sound financial venture. Proponents of a periodical can serve their purpose best through the direction of their energies toward the attainment of that level of membership.

We recommend to the Society (1) that our Committee be dissolved and (2) that the establishment of a quarterly journal receive no further consideration until such time as a true need can be demonstrated and our membership shall have increased to a figure that would guarantee the publication adequate financial support.

We feel that with the submittal of these recommendations we have fulfilled the purpose for which our Committee was established. We should like, nevertheless, to go beyond that purpose and to inquire into the cause of the almost perennial pressure for a quarterly journal during a period when the Editor finds it difficult to obtain sufficient acceptable material for the *TRANSACTIONS*. The real motive behind this pressure would appear to be, not a desire to expand the publication facilities of the Society, but rather to modify them so as to make possible the issuance of papers not acceptable under current editorial policies. An undercurrent of dissatisfaction was detectable when the predecessor to the present Committee was authorized by resolution at our Seventy-sixth Annual Meeting. It came to the surface briefly at our Seventy-ninth Annual Meeting when an attempt was made to deprive the Editorial Board of one of its traditional powers. It is to be sensed once more in the ambiguous but suggestive wording of the resolution passed at our last meeting which held that a periodical journal should "... include regional and special technical problems, allowing maximum space in the annual *TRANSACTIONS* for problems having international and general application." Editors of the *TRANSACTIONS* have been aware of objections to their selection and rejection of papers. In fact, our present Editor found these objections so distressing that he formally requested the adoption of an official editorial policy at the meeting of the Executive Committee, held in Milwaukee on March 5 of this year.

The following paragraph from the 1949 report of the Editorial Board (*TRANSACTIONS*, Volume 79, p. 277) states rather definitely the policy under which the *TRANSACTIONS* have been edited since 1936 and which almost certainly will be continued indefinitely unless the Society by official action decrees otherwise.

In our philosophy the obligations of the Editorial Board to the Society as a whole have outweighed all others. The members, whose support makes the publication of the *TRANSACTIONS* possible, deserve the very best volume that we can give them. They are entitled to protection from poorly arranged tabu-

lar material, cluttered-up illustrations, and textual matter burdened with clichés, irrelevancies, ambiguities, and solecisms. Authors should count it a privilege, not a right, to have papers appear in the *TRANSACTIONS* and should accordingly be happy to conform to the standards of that publication.

Perhaps this policy is wrong. Perhaps the *TRANSACTIONS* should be expanded or other outlets established to make provision for the publication of articles not acceptable under present standards. Perhaps the Editors should be instructed to accept papers of a popular or semi-popular character, accounts of contemplated programs, scientific articles based on sketchy and inconclusive preliminary data, discussions that contain no original information or points of view, papers of strictly temporary or local interest, . . . Perhaps authors should not be required to conform to the usages prescribed annually in the *TRANSACTIONS* or to give so much care to the preparation of their manuscripts. Perhaps the Editorial Board has been too exacting in its efforts to maintain the *TRANSACTIONS* as a scientific publication with the highest possible standards of both composition and content. Perhaps the whole policy of the Society with respect to publications needs to be reviewed. If so, it would be better to have all problems brought out in the open and each question resolved on its own merit. The devious approach of pressing for unneeded expansion of facilities does not recommend itself.

For the benefit of our organization and for the assurance of our Editorial Board, this Committee recommends that the members discuss among themselves and ultimately in open meeting questions relating to the Society's publication policies.

COMMITTEE ON EMPLOYMENT AND PROFESSIONAL STANDARDS

T. H. LANGLOIS

This Committee was named by the President pursuant to a resolution adopted at the eightieth annual meeting of the Society. During the past year, at the request of the Chairman, members of the Committee have forwarded to him and to each other their individual notes and comments on the subject of employment and professional standards, and the statements to follow are, in large part, abstracted from these communications. Some of the views expressed by members on the question of professional standards may be summarized in three categories:

1. Standards applicable to student training. There was unanimous agreement that undergraduate training should be broad in the humanities with emphasis on the use of language and on course work in biology, with some field experience desirable. Several members expressed the definite opinion that specific courses in fishery biology at the under-

graduate level should be avoided, to provide more time for courses of fundamental character. Specialized training in fishery research and management should, in this view, be received at the graduate level, and in conjunction with biological field work

2. Standards applicable to administration of technical work and workers. On the question of "directed" research, rather strong individual views were expressed. It was recognized that general direction is necessary to keep an investigational program aimed at its objective, but attempts by administrators to exercise day by day supervision of the work of professionally competent investigators were regarded as objectionable. In general, it was felt that the employer should provide a suitable environment for the research man, approve his project and require a report upon completion, but leave details of planning and execution to the investigator.

There was some disagreement as to whether or not an administrator should himself possess a scientific background. But it was agreed that the administrator should acquire a sufficient appreciation of research methods and existing problems to realize the generally greater value of long-term studies leading to valid conclusions, as opposed to "quickie" projects dictated by the expediciencies of the moment.

3. Standards for professional ethics. Listed by members as crimes against professional ethics were: plagiarism, failure to give credit, pretentiousness, unjustified criticism, "apple-polishing," "hog the show," jealousy, perfectionism, "political" science, attempting to prove a pet idea, and evangelism.

Other suggestions were that the professional research worker should: refuse financial support proffered on political grounds for projects not really in need of study; refuse to permit his completed reports to be shelved; assume responsibility as needful for gaining public acceptance of new facts and ideas; and stick with a given task until it reaches a logical stopping point, preferably completion, before accepting opportunities for more lucrative employment elsewhere.

Detailed discussions of professional standards, among members of the Committee, have been too voluminous and inconclusive for further treatment here. The same is true for discussions of employment standards and requirements. It may be noted that certain professions similar to ours have devoted a number of years to study and discussion before adopting anything approaching a standardized code on these subjects. It appears likely at present that this Committee will be continued, possibly even be made a Standing Committee. The foregoing comments may, therefore, be accepted as a progress report indicative of the trend taken by the thinking of present Committee members on certain segments of their assigned responsibility. It may be hoped and expected that continued thought will lead to crystallization of concepts extending into all aspects of the problem of employment and professional standards.

POLLUTION ABATEMENT COMMITTEE

CLARENCE M. TARZWELL

In order to understand adequately and plan effectively for the abatement of pollution, it is essential to have a comprehensive grasp of the problem as it now exists. It is essential to know what constitutes a pollutant; the various classes of pollutants and their general effects; where pollution occurs and when it occurs; how the various pollutants act; the extent of pollution; and what is being done or what can be done for the abatement of the various types of pollution.

First, it is desirable that the term pollutant be clearly defined. A pollutant may be defined as any material, substance or organism which, when added to our waters, creates a health hazard, produces a noxious condition, damages a water for domestic or industrial uses through the production of tastes and odors, toxic effects or undesirable physical or chemical conditions, destroys or reduces the aesthetic value of the water or adversely affects aquatic life.

Because we are interested in fish production and management, we are most concerned with the biological effects of pollution. On the basis of their biological effects on aquatic life, pollutants may be roughly classified into three groups:

1. Inert solids—such as materials added to streams due to land erosion, bank erosion, various types of mining operations, certain industrial operations, etc.
2. Oxygen depleting wastes — largely organic materials, such as domestic sewage and wastes from canneries, creameries, meat and fish packing plants, cheese factories, tanneries, breweries, distilleries, etc.
3. Toxic wastes—which generally arise from industrial operations and include acids, strong bases, certain of the heavy metals as copper, zinc, lead, etc., and certain salts. Cyanide, phenols and many complex inorganic and organic materials arising from industrial operations are also toxic to fishes and other aquatic life.

Available data showing where and when pollution occurs, how it acts and the extent of pollution are being compiled by the Water Pollution Control Division of the Public Health Service. Data on the nature and extent of pollution have been compiled with the aid of the various states, and preliminary reports have been prepared by each of the 10 River Basin offices. These reports have been summarized in a publication entitled *Water Pollution in the United States* which appeared in May, 1951.

In this publication, it is pointed out that there are over 22,000 sources of pollution in the United States; 11,800 municipal sewer systems and 10,400 factory waste outlets. Despite the reduction of waste by 9,300 treatment plants (6,700 municipal and 2,600 industrial) the waste dis-

charged into our waters equals that from over 150,000,000 people. There is need for 6,600 more municipal sewage plants or additions and some 3,500 more industrial waste treatment plants or additions. There are 7,000 other needs (1,600 municipal and 5,500 industrial) as yet unascertained.

The pollution problem has been increasing rapidly during the last few years. One hundred years ago, our country was largely rural with only a few cities and factories. Today, three out of five Americans live in cities and the majority of our population derives its livelihood from industry. Our industrial production has more than doubled in the last 15 years. As we concentrate our population in small areas, the products of our soil are shipped into these areas where they are partially utilized before being dumped into our streams to be carried to the sea and buried in deltas. This process is not conducive to the maintenance of our soil resources and is a double waste in that it destroys many of the uses of our water resources. Thus, pollution is a factor contributing to the shortage of water for industrial use. The National Association of Manufacturers states that a shortage of water for industrial purposes, just as a shortage of manpower, of raw materials or of capital, could defeat our hopes for future growth and prosperity and even imperil our national safety.

A large portion of our pollution comes from our municipalities. We have some 11,811 municipalities with sewers which discharge the wastes from a population of 91,762,000 persons. Of these 11,811 municipalities, some 6,628 have sewage treatment plants which serve a population of some 56,494,000. The total discharge from all the municipalities is not known but 6,921 of them discharge materials having an oxygen demand equivalent to a population of almost 48,000,000. Of the total number of communities 3,099 provide primary treatment for the wastes from about 24,600,000 people. Secondary treatment is provided by 3,529 municipalities having a population of almost 32 million. However, 5,156 municipalities having a population of over 35 million do not provide any treatment.

Another means of treating organic wastes is the septic tank. It has been estimated that there are 4,400,000 septic tanks in the country serving a population of about 17 million. This mode of treatment compares very favorably with secondary treatment.

Industry also adds a great deal of oxygen depleting wastes. Of the 10,401 industries discharging wastes, some data on treatment facilities are available for 6,254. Of these, 2,595 are treating their effluent while 3,659 are not. Information is not available as to the toxicity of wastes and the number discharging wastes toxic to aquatic life.

An important consideration in the handling of domestic and industrial wastes is the adequacy of the capacity of the plant handling the wastes. Among municipalities treating their wastes 3,531 had plants

with adequate capacity, 2,541 had plants which were inadequate, and the adequacy of 583 is not known. Among the industrial plants providing treatment 1,090 had adequate facilities, while 657 did not, and the adequacy of 848 plants is not known.

During the past few years, there has been a substantial increase in the number of waste treatment plants. During the four year period 1946 through 1949, there was placed in operation a total of 646 municipal plants serving a population of almost 10 million persons. During the same period, 517 industrial waste treatment plants were constructed. In addition, there is considerable work planned or underway. In the municipal field, 326 sewage treatment plants are under construction, plans for construction have been approved for 854 and plans are under preparation for 961 more. For the treatment of industrial water 114 plants are under construction, final plans have been approved for 124 more and plans are under preparation for 410.

A great deal yet remains to be done. For the treatment of municipal wastes, it is estimated that 4,209 new plants are needed; 722 others need replacements, and additions or enlargements are needed for 1,645 others. Much the same situation exists in the treatment of industrial wastes, as some 2,793 new plants are needed, 98 should be replaced, and additions or enlargements are required for 591 others.

In general, pollution is most widespread and severe in the eastern portion of the United States. Pollution problems and progress toward their solution differ in various portions of the country. As regards populations served by sewage treatment plants, the Great Lakes Basin and the Western Gulf and Colorado Basin lead, while the Ohio Basin ranks last. From the standpoint of the adequacy of treatment plants, the Middle Atlantic Coastal area (New York to North Carolina) ranks first and the Lower Mississippi area last. In the construction of new plants, the Upper Mississippi area ranks first and California second. The Middle Atlantic Coastal area ranks first in the construction of industrial waste treatment plants. From the standpoint of additional facilities needed for meeting the pollution problem, the greatest needs for municipal treatment are in the Ohio Valley, the Southeast area and in New England. Needs for additional industrial waste treatment plants are greatest in the Ohio Valley, the Middle Atlantic Coastal area and New England.

A questionnaire was submitted to the state health departments and fish and game commissions of Arkansas, Louisiana, New Mexico, Oklahoma and Texas, requesting information on their pollution problems. Of the ten questionnaires sent out, seven were returned. These seven represent all of the above states except Louisiana. Salt water from oil wells and oily wastes from the production and refining of petroleum products is the main pollution problem in south-central Arkansas. The newer fields provide systems for injecting the salt water back into the ground, but the older fields continue to pollute the streams. In

Arkansas, domestic pollution is listed second in order of importance. Of 116 towns with public sewer systems, 98 (85 percent) have sewage treatment plants. Sixty percent of these are adequate and 19 new plants and one addition have been built in the last two years.

New Mexico listed the silt load of streams as being the most important pollutant during the 1950-51 period. Domestic sewage, wastes from oil wells and refineries and mining wastes were ranked next in order of importance. In 1950-51, mining for uranium increased mining pollution so that it came close to being second in importance. Of much lesser importance were miscellaneous industrial wastes such as sulfuric acid from delinting plants and oil wastes from round houses.

In Oklahoma, pollution with wastes from oil wells and refineries was the only type mentioned by the State Game and Fish Department. The State Department of Health lists salt water from oil wells first, domestic pollution second, mining wastes third, oil refinery wastes fourth and miscellaneous industrial wastes fifth.

The Texas Game and Fish Commission listed salt water from oil fields as first in importance, waste oil from refineries second, then, of much lesser importance, coal mine wastes, pulp and paper wastes, chemical plant effluents, and miscellaneous industrial wastes.

It is apparent that the most important pollutant in the southwest is bleed waters from oil wells. The main violators are small companies which operate old fields and do not have the capital to install the injection well system for returning the brines to the ground. Domestic pollution ranks second, with the limiting factor in its control being money. Steps have been taken in Arkansas and New Mexico to provide technical aid to municipalities for the construction of sewage disposal plants, and if this were carried through in the other states and additional funds provided the problem could be solved.

In California, considerable progress in the abatement of pollution affecting fish life has taken place during the past two years. In 1948, critical conditions led to the employment by the Division of Fish and Game of two sanitary engineers to make surveys and to supply technical assistance in the prosecution of pollution cases. In a number of places in the State, the war-time and post-war expansion of population and industry has seriously overloaded the existing waste treatment facilities. At other locations disposal facilities have never been constructed, and the resulting water pollution is more serious than ever before, particularly in the Central Valley and San Francisco Bay areas.

In 1949, the State Legislature enacted a sweeping series of changes in the existing laws governing water pollution. The legislation established a State Water Pollution Control Board and nine Regional Boards for the purpose of coordinating pollution control activities and establishing pollution policies at the local level. These laws provide that any persons desiring to discharge sewage or industrial waste apply to

the Regional Boards for requirements that will have to be met by the operator of the disposal system. The Regional Boards establish these requirements after consultation with the State and local agencies interested in the problem. The Division of Fish and Game has the responsibility of furnishing any technical information or undertaking investigations having to do with the fish and wildlife aspects of any case of pollution which may be requested by the Regional Boards.

The past two years have seen a great deal of construction of facilities for domestic sewage treatment, as the post-war building programs of cities have been activated.

Much work needs to be done before the industrial waste problems in the state can be solved. These problems involve especially the food processing and lumber industries.

Probably the most encouraging development during the past few years has been the increase in the number of potential pollution cases that have been prevented.

IMPORTANCE AND CONTROL OF VARIOUS TYPES OF POLLUTION

Silt and other inert solids added to our streams are our most widespread and, perhaps, most important pollutants. The greatest source of these materials is land erosion produced or aggravated by unwise agricultural practices, overgrazing, deforestation and fire. Bank erosion, mining operations, dredging and certain industrial operations also add large quantities of these materials to our streams and lakes. Silt and other eroded materials have choked and destroyed many streams. In others, pools have been filled, spawning areas destroyed and fish food production reduced through the covering of productive areas. Mud and silt added to our waters through soil erosion reduce light penetration and result in reduced photosynthesis and smaller plankton populations, which serve as food for many fish. Muddy waters also favor the coarse species over the game fishes which feed by sight.

Abatement of silt pollution is a protracted, large and difficult problem. Several government agencies are actively engaged in programs for the prevention of soil erosion. If silt and other inert solids come to be recognized by the general public as pollutants, progress in this control will be more rapid.

Toxic wastes constitute a serious problem which is receiving increasing attention by the various states. New York, California and Washington have shown interest in toxicity standards and have prepared preliminary lists of permissible concentrations of certain toxic materials. If such toxicity levels are established, it is desirable that they be uniform throughout the states, so that industry will not tend to concentrate in those areas having more lenient standards. The construction of waste treatment plants adds to an industry's capital investment and overhead. Private industry is competitive. An industry will hesitate

to spend a substantial sum on waste treatment works that may give a competitor the advantage of lower production costs. Uniform "effluent standards," restricting the concentrations of toxic materials in every industrial plant effluent to levels which would be harmless, regardless of the size and nature of receiving body of water, cannot be strongly recommended at the present time, for various reasons. However, there should be some uniformity of the maximum permissible degree of contamination with toxic materials of all waters which are to be used for industrial waste disposal and which are also valuable fishing waters. The toxicity of many waste materials varies greatly according to the character of the receiving water. Toxicity bioassays, involving the use of fish as reagents, are useful for evaluating the toxicity of effluents and estimating the amount of waste which can be added to a given receiving water without causing fish mortality. Bioassays might well become part of routine procedure in the disposal of toxic wastes by industry. However, if uniform chemical standards specifying maximum concentrations of specific toxic substances in receiving waters are to be adopted, these should be established on the basis of the toxicity of these substances under the most unfavorable conditions. If based on toxicity under average conditions, or other conditions under which the substances in question are not most toxic, the standards are bound to prove inadequate and misleading in many instances.

The problem of industrial pollution is rapidly becoming larger and more widespread. Water for industrial purposes is becoming scarce and industry itself is showing an active interest in pollution abatement. Methods are not available for the treatment of many industrial wastes. Research is needed for the development of adequate and economical treatment processes. Many industries are building up technical staffs for the solution of their problem.

The most practical and economical method of performing the fundamental technical task which confronts those industries concerned with waste disposal appears to be through coordinated effort—in a word, teamwork. It is believed that by bringing together industries which have what might be termed a community of interest—insofar as wastes are concerned—duplication of effort and needless expense can be minimized.

A meeting of representatives of 22 of the nation's leading industries concerned with solving difficult industrial waste disposal problems affecting the quality of the country's water resources was held in May, 1950, on invitation of the U. S. Public Health Service. At this meeting there was established a National Technical Task Committee on Industrial Wastes. The committee drew up the broad outlines of an Industrial-Federal Government approach to the control of water pollution caused by industrial wastes. It was agreed that the purpose would be "to effect an improvement in the quality of water resources in the nation," and its objective would be "to perform technical tasks per-

taining to industrial wastes in cooperation with the Public Health Service and all others concerned with improving the quality of our water resources."

The Committee set for itself three initial tasks:

1. Assemble a list showing sources of information on processes and practices known for using, treating, and controlling industrial wastes.
2. Prepare a tabulation of research projects concerned with utilization treatment and disposal of wastes, those under way and those contemplated.
3. Provide a list which will define problems that confront a given industrial group and for which there is no satisfactory solution; particularly those which are common to more than one industry.

The Task Committee established four major task groups representing different major types or classes of industry. These task groups will act as working committees to carry out the functions of the committee at large, and will consist of sub-committees representing specific industries, food, mineral products, chemical processing and general industry.

In general, conditions of pollution are not nearly as acute in Canada as in the United States. This is due in large part to very extensive water areas and to a much smaller population. In Ontario, however, serious problems have arisen. At the request of the Provincial Government, a special committee was set up by the Research Council of Ontario to study the problems of pollution. It is known as the Advisory Committee on Industrial Wastes and corresponds to the National Technical Task Committee on Industrial Wastes in the United States. It is studying the wider problems of industrial waste in the Province and is working closely with the Sanitary Engineering Division of the Provincial Department of Health. The Advisory Committee on Forestry Research is also active on problems concerning the disposal of wastes from the paper industry.

Of the three main types of pollutants, those causing oxygen depletion are most amenable to control. Methods for control are now known. It remains only for money and facilities to be provided for their control. Building a sewage treatment plant lacks appeal for taxpayers who may not be entirely convinced of the need. By and large, the ultimate solution of the nation's pollution problem will be governed by public support for effective action. The facts in pollution should be made far more widely known to the general public in order to inform them of the problem and awaken their interest in its solution. Within the past year definite progress has been made toward informing the public concerning our pollution problem.

In spite of limitations in appropriations by Congress to the Water Pollution Control Division, Federal Security Agency, under public law 845 (the Barkley-Taft Federal water pollution control act passed

in 1948) real progress has been made in the last year in informing the general public on the story of the national pollution problem, the need for control, and how this may best be achieved.

In the last two years the Water Pollution Control Division has done an outstanding job of publishing technical, semi-technical, and popular printed material, describing the general pollution situation, as well as pinpointing specific pollution problems by river basins.

Private organizations, such as the Izaak Walton League, have distributed nationally throughout the year many thousands of copies of publications, federal as well as their own, dramatizing the pollution problem. There is an increase of activity on the part of local organizations to bring about pollution abatement in their own communities and regions. There seems to be a growing willingness and desire on the part of industry and state health departments to do something about those aggravating local pollutional conditions. That is, without question, a result of the continuous hammering away at the need for clean-up by all agencies and organizations involved.

There is need for all agencies and organizations concerned to continue to keep aggressively educating the general public with regard to pollution problems, successful abatement activities, and the need for control where it is not now being practiced. Private citizens must not sit back, now that some progress is being made, and forget about pollution control activities. We still have a long way to go.

That pollution *can* be cleaned up has been proven time and time again if the citizenry, as well as the state government, will insist on carrying out the directives of state statutes aimed at abating pollution. The nationally publicized activity in this connection of the state of Pennsylvania in the last two years is a case in point. If it can be done in Pennsylvania, it can be done in any state in the Union.

A significant indication of the willingness of some segments of industry to cooperate in this activity has been the wide distribution of the film *Clean Waters* by a major electric company.

In summation, the picture is encouraging. We have more tools to work with than we had 5 years ago, and more are coming to the fore all the time. It behooves fish management technicians, who are concerned with an aquatic resource seriously affected by some types of pollution, to give increasing attention to specific cases where one or another type of pollution affects a fish population or a fish food population, and thus destroys the resource. One place where a fishery biologist could perform a real service is in working out a detailed study, not only of the total effect of a pollution outbreak after it has occurred, but in determining the *potential* population of aquatic vertebrates, both fish, insects, and other cold blooded vertebrates which are not now in existence through the pollution of any given waterway. There are many already sorely polluted streams which, if cleaned up, could pro-

duce a very significant and usable aquatic resource. Little, if any, work has been done on determining this potential. Here is one of the great effects of pollution which has gone unrecognized for a long time. Information of this nature would give those who are attempting to bring about clean-up some very constructive and factual ammunition to use in arousing public interest and public demands for abatement.

The total cost of a national municipal and industrial pollution abatement program would range roughly from \$9 billion to \$12 billion, depending on the water uses finally chosen.

When we, the people, determine the best uses for our streams, lakes and bays, with due consideration of all the manifold factors that enter such a complex evaluation, the precise cost of reclaiming our waters can finally be ascertained. In the final analysis, solution of the nation's pollution problem depends on public support.

REPORTS OF SESSIONAL COMMITTEES

TIME AND PLACE COMMITTEE

MARION TOOLE

The Time and Place Committee met with the corresponding committee of the International Association of Fish, Game, and Conservation Commissioners. It was agreed that the 1952 meetings of the two organizations shall be held in Dallas, Texas, September 8-12, with the American Fisheries Society sessions scheduled for September 8-9, those of the International Association for September 11-12, and September 10 reserved for a joint field trip and annual banquet.

AUDITING COMMITTEE

JOHN S. GOTTSCHALK

The Auditing Committee has met and examined the books of the Society for the fiscal year 1950-1951. We find that all income is accounted for, that the financial records are correct to June 30, 1951, and that the financial standing of the American Fisheries Society is as set forth in the Treasurer's Report.

The Committee wishes to commend the Secretary-Treasurer and his assistants for their excellent handling of the Society's records.

NOMINATING COMMITTEE

RUSSELL P. HUNTER

The Nominating Committee submits the following list of names of members to serve as officers and as members of standing committees:

OFFICERS

President.....W. J. K. Harkness, Ontario
First Vice-President.....Ralph Hile, Michigan
Second Vice-President.....Fred A. Thompson, New Mexico
Librarian.....W. C. Beckman, Colorado

Committee on International Relations

W. C. Senning, New York, *Chairman*
Richard S. Croker, California
William C. Herrington, District of Columbia
Paul R. Needham, California
Fernando Obregon, Mexico
John Van Oosten, Michigan
A. L. Pritchard, Ontario

Committee on National-State Relations

Wayne D. Heydecker, New York, *Chairman*
John S. Gottschalk, District of Columbia
H. R. Morgan, North Dakota
Ernest Swift, Wisconsin
Alan C. Taft, California

Committee on Hydrobiology and Fish Culture

James W. Moffett, Michigan, *Chairman*
F. E. J. Fry, Ontario
O. R. Kingsbury, New York
Richard B. Miller, Alberta
Clarence F. Pautzke, Washington
Lyle M. Thorpe, Connecticut
A. V. Tunison, District of Columbia

Committee on Commercial Fisheries

W. H. R. Werner, Ontario, *Chairman*
Howard K. Balch, Wisconsin
J. Nelson Gowanloch, Louisiana
John L. Hart, British Columbia
Carl F. Kolbe, Ontario
Francis W. Sargent, Massachusetts
Richard T. Whiteleather, District of Columbia

Committee on Names of Fishes

Reeve M. Bailey, Michigan, *Chairman*
Frank T. Knapp, Texas
Ernest A. Lachner, District of Columbia
John E. Marr, California
George S. Myers, California
Edward C. Raney, New York
William E. Ricker, British Columbia

RESOLUTIONS COMMITTEE

E. B. SPEAKER

1. FAVORING THE TACKETT BILL

WHEREAS, The multiple use nature of the U. S. forests is hereby recognized, and

WHEREAS, Funds for the development of fish, wildlife and recreational resources on these national forests have not been available for several years, and

WHEREAS, Existing recreational facilities have deteriorated and new and expanded camp grounds, trails and facilities for the public are needed to meet a greatly increased demand; now therefore

BE IT RESOLVED, That the American Fisheries Society does hereby recommend the passage of the Tackett Bill, HR 565, which provides that 10 percent of all monies received from National Forest income shall be available for the development, maintenance and operation of National Forest recreational resources including fish and wildlife, and

BE IT FURTHER RESOLVED, That the Secretary of the Society be instructed to send a copy of this resolution to the Chairman and members of the committees considering the Tackett Bill.

2. LOWER SNAKE RIVER DAM CONSTRUCTION

WHEREAS, The Salmon River is one of the greatest producers of anadromous fishes in the Columbia Basin, and

WHEREAS, The construction of the dams in the Lower Snake River would materially affect production of all Snake River tributaries including Salmon River by obstructing the free passage of salmon to their spawning grounds, and

WHEREAS, Such obstructions would significantly reduce the sport fishery of Salmon in Idaho and have serious effect on the commercial salmon fishery of the Pacific coast; now therefore

BE IT RESOLVED, That the American Fisheries Society continue to express its disapproval of present plans to construct the Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams in the Lower Snake River until all other potential sites with less damage to fish and wildlife are developed.

3. PUBLIC FISHING RIGHTS ON FEDERALLY IMPOUNDED WATERS

WHEREAS, Many good fishing waters are being impounded by the Bureau of Reclamation and the Army Engineers for power development, irrigation of new lands, and flood control, and

WHEREAS, These waters basically belong to the people of the state, and

WHEREAS, In years to come the jurisdiction and management of these waters and the area surrounding them may revert to private, corporation or municipal ownership, and access of the general public restricted therefrom; now therefore

BE IT RESOLVED, That the American Fisheries Society hereby request the Bureau of Reclamation and the U. S. Army Engineers to provide in the initial planning and agreements of all dams and impoundments that public fishing rights will be protected, and free access thereto provided in perpetuity and so encumbered in the deed of the lands thereto, and

BE IT FURTHER RESOLVED, That these agencies provide in the initial planning of such projects as well as in the operation of all existing impoundments provisions for a minimum conservation pool in order that adequate fish life may be maintained in these impoundments.

4. PROPOSED AMENDMENT TO THE BY-LAWS

WHEREAS, No provision has been made to authorizing a Division of the American Fisheries Society to submit resolutions to Federal or state agencies, or to organizations or individuals, and

WHEREAS, Additional Divisions may be added from time to time as provided by the Constitution of the Society, and

WHEREAS, Conflicting resolutions may be passed by such Divisions; now therefore

BE IT RESOLVED, That each Division shall submit to the parent Society for consideration before release, all resolutions except those of a courtesy nature.

BE IT FURTHER RESOLVED, That resolutions of an emergency nature after approval by the Division may be submitted by the Chairman, when so authorized, to the Executive Committee of the Society through its Secretary-Treasurer; and

BE IT FURTHER RESOLVED, That if approved by the Executive Committee, such emergency resolutions may then be issued in the name of the Division.

5. RESOLUTION TO MR. YOUNG

WHEREAS, The American Fisheries Society, assembled at Rochester, N. Y., September 14, 1951 at its Eighty-First Annual Meeting, has been advised of the illness of a faithful friend and colleague, Mr. Earl Young; now therefore

BE IT RESOLVED, That the Secretary of the Society be instructed to extend our good wishes to Mr. Young for his early recovery.

6. COURTESY RESOLUTION

WHEREAS, The American Fisheries Society has been the recipient of gracious and considerate hospitality at its Eighty-First Annual Meeting at Rochester, New York; now therefore

BE IT RESOLVED, That the Society express its appreciation and gratitude to the Honorable Perry B. Duryea, Commissioner of the New York State Conservation Department for the successful arrangements and many courtesies extended to the Society;

To members of the New York State Conservation Department for their splendid assistance;

To the Genesee Conservation League for outstanding hospitality afforded the members of the Society and their ladies; and

To the Management of the Seneca Hotel for courtesies and pleasant services rendered.

BE IT FURTHER RESOLVED, That this Society express its appreciation for the excellent cooperation and participation in the program of this meeting by the American Society of Limnology and Oceanography.

7. AD HOC COMMITTEE ON EMPLOYMENT AND PROFESSIONAL STANDARDS

WHEREAS, The Ad hoc Committee on Employment and Professional Standards has reported to the society and has indicated that these studies merit continuance

NOW, THEREFORE, BE IT RESOLVED, That the incoming President appoint a committee to continue these studies for another year and to report at the next meeting of the Society; such report to include the recommendation as to the necessity of further study.

All resolutions except number 4 were adopted on motion of E. B. Speaker, chairman of the Committee. Mr. Sprecher moved that resolution number 4 be passed as an amendment to the By-Laws with the recommendation that the matter be brought up at the 1952 meeting as an amendment to Article VI of the Constitution. Motion was carried.

CONCLUDING BUSINESS

The Retiring President: The slate of officers and committeemen submitted by the Nominating Committee has been elected by unanimous vote of the Society. It is an honor to welcome the new President, and I bespeak for him the same good cooperation and friendly help I have enjoyed during the past year.

I now ask that Dr. A. G. Huntsman, of Ontario, and Dr. John Van Oosten, of Michigan, escort Dr. W. J. K. Harkness, of Ontario, the new President, to the Chair. [Applause.]

The New President: I wish to thank you, my friends, for the honor you have conferred upon me. I am very conscious, of course, that in the election of a President, much more than the individual himself is considered. The men with whom any person is associated professionally constitute his background, and in honoring him the group is honored. I wish to pay my respects to my fellow workers in Ontario, and to extend their thanks for the honor conveyed to them by my election to the highest office of the Society.

At this time I wish to reappoint the existing editor and editorial committee. Also the following members will be reappointed to the committee on employment and professional standards:

T. H. Langlois, Ohio, *Chairman*
Clinton L. Baker, Tennessee
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Upon motion, the Eighty-first Annual Meeting of the American Fisheries Society was adjourned.

Appendices

INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1952)

Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your Editorial Board (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the *Transactions*.

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals (Government Printing Office Style Manual; University of Chicago Style Manual). Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. MANUSCRIPT MUST BE TYPEWRITTEN DOUBLE-SPACED, including titles, headings, legends for tables and illustrations, and literature citations. Use one side only of sheet. Do not fold manuscript. Write manuscript only in simple upper and lower case. Do NOT USE ALL CAPITAL LETTERS FOR ANY PURPOSE AND UNDERScore ONLY WHERE ITALICS ARE INTENDED. NO MANUSCRIPT WILL BE ACCEPTED UNLESS IT CONFORMS TO THIS STYLE.

2. CARBON COPIES WILL NOT BE ACCEPTED. Do not use thin, transparent paper. Heavy bond paper is preferred.

3. MARGINS at top, bottom, and both sides must be no less than $1\frac{1}{4}$ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. PAGES must be numbered in consecutive order, including the literature cited, tables, charts, and photographs. Tables and legends of charts and illustrations must be inserted near their place of reference in the text.

5. ILLUSTRATIONS. Make separate pages of tables with headings (not of leader work), of legends of diagrams, charts, and illustrations, and limit the number to those absolutely necessary to clarify or supplement text. *Tables and cuts cost money!* Only sharp, glossy photos can be used. All drawings, charts, and diagrams should be prepared in waterproof India ink on Bristol Board, other perfectly smooth white paper or cardboard, or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the shading lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed $4\frac{1}{4}$ by $6\frac{1}{2}$ inches (inclusive of legends) when reduced. All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend. The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, charts, and tables, and with Arabic, not Roman, numerals.

6. FOOTNOTES in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do

not break a line of text to insert footnote. Separate the footnote from the text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1.

7. THE TITLE of the manuscript, together with the author's name (write out in full either one or both of the Christian names and do not use "by"), position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

REPORT ON THE DISEASES OF BROOK TROUT

JOHN EDWARD DOE

Department of Conservation, Lansing, Michigan

8. UNDERScore (*italics*) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius*. *Do not underscore any words unless italics are intended.*

9. Inspect papers in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. BIBLIOGRAPHIC REFERENCES in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

LITERATURE CITED

DOE, JOHN C., J. W. BROWN, and H. W. GREEN

1939. Report on the diseases of brook trout. *Trans. Am. Fish. Soc.*, Vol. 68 (1938), pp. 450-461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and very inaccurate. Help us correct this situation.

11. TABLES. Every table should have a heading and must be typewritten on a separate page. Insert tables among the text pages near the points where they are

Item	Number of fish	Percentage of total	Average length millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	\$0.25

discussed. In preparing tables please be certain that they are not too large to appear on a single printed page. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word "number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date*, in body of table), and capitalize, as a rule, the first word only in headings in the 1st column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

12. CAPITALS. Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Hoover Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. ABBREVIATIONS.

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures, F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

Number, if preceding figures—No. 125; otherwise spell out.

United States, if preceding name of a department or a bureau of a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana*.

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5-September 2.

Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage, 12 percent, a percentage of 25.5.

14. NUMERALS. Spell out all *isolated* numbers less than 10, but use figures in a group of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits (except round numbers of approximations: estimated at five hundred; a thousand fish), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for all enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth inch). For example: \$3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish

died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938; the 20th day of March; 1937-38; 4.5 p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch trout; 120 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such indefinite expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout.

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. USE OF HYPHEN. Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentence: "This species is adapted to *"cold water."* "Trout are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III. SUBJECT MATTER

16. CONDENSE YOUR PAPER to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. PAPERS WHICH ARE TOO POORLY WRITTEN WILL BE REJECTED.

17. BE DEFINITE IN REFERENCES TO SPECIES. The scientific name, and wherever needed the *complete* common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "bass," trout," and "pickerel" apply to any one of several species. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. THINGS TO AVOID. Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "show," "found," "gave," and "present" are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives*. Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: "*This* was true in every case." "*The mortality* was high in every pond."

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. ABSTRACT OF PAPER. Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

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Printed in U. S. A.